

The University of Chicago

SCIENTIFIC MANAGEMENT AND
THE COTTON TEXTILE INDUSTRY

A PART OF A DISSERTATION SUBMITTED TO
THE GRADUATE FACULTY IN CANDIDACY
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

THE SCHOOL OF COMMERCE AND ADMINISTRATION

1930

By

HENRY JOSEPH REHN

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CHAPTER I

INTRODUCTION

The purpose of this study is to make a brief critical survey of the literature of management and to select from it that which seems to the writer to constitute the necessary elements of good management, that which can be termed Scientific Management. Scientific Management as thus selected from the literature is then placed over against the actual management of a number of small cotton mills. From this comparison of Scientific Management and a small segment of a certain industry some deductions can be made regarding the validity of the theories presented in the management literature.

Those instances where the practice coincides with the theory of management constitute presumptive evidence that the theory is right. Where the theory and practice do not coincide the theory may be in error; it may not be applicable to the particular situation, or the practice may be in error. In those cases the evaluation of Scientific Management must be on a less objective basis.

All except one of the mills included in this study are small units, and management therefore was not as specialized as it could be in larger mills. Many of the theories of Scientific Management which apply more to the control of large units can therefore not be evaluated as readily from this study as can those theories that apply also to smaller units.

The study of Scientific Management theory consisted of an examination of the literature on the subject. Since 1911 there has been an abundant accumulation of literature dealing with the application of science to the problems of business management. Much of this voluminous literature is practically worthless.

The writer is of the opinion that Scientific Management at its best is not to be found exclusively in the writings of Frederick W. Taylor, Harrington Emerson, nor in the writings of any small group. Materials have therefore been drawn from many writers and many sources. It has been an attempt to synthesize what seems to the writer to represent the best thought on the subject of management.

The field study was confined, with one exception, to a number of mills located in Texas. The exception was a large mill in

South Carolina, where several days were spent studying the situation.

Direct personal contact was established with eleven of the twenty-two mills located in Texas. These contacts consisted of interviews with the mill management, and in most cases also visits to the mill. The study covered a period of nine months, two of which were actually spent at the mills.

The actual mill operations and the management of two of these mills were studied in detail. A less detailed study of six other mills indicated that the two studied in detail were typical illustrations of small coarse-goods mills. A number of the managers also indicated that they believed the two mills studied in detail were typical examples.

During these visits to the mills hours were spent in conference with the mill manager. In the case of the two detailed studies lengthy interviews were also obtained with the mill superintendent, the overseers, and the bookkeeper.

Time did not permit a detailed and extensive observation of the actual management in operation so that the management practices might be deduced from the actual operations. It was therefore necessary to determine the management methods by actual direct questioning of the mill manager, the superintendent, the overseers, and the bookkeeper. It is recognized that the results from this method of investigation may be biased and may indicate better management than actually exists; also, the picture obtained by this method is usually limited to those matters upon which there was direct interrogation. However, in addition to this questioning, the records and reports were usually made available for examination. This permitted ready verification of many of the control methods used. Such matters as the inspection system, the plant layout, the results of scheduling production, and some of the labor policies were readily verified by direct observation.

In addition to these direct contacts, some comparable data on five mills were obtained from a recent study of a number of Texas mills.¹

The Cotton Textile Industry

Cotton has been made into fabrics for many centuries,² but

¹ Sidney J. Adams, Managerial Control of Textile Mills. A Master of Business Administration Thesis. Austin, Texas, 1928.

² J. A. B. Scherer, Cotton as a World Power (New York, 1916), p. 16, cites a reference to cotton cloth in the "Rig Veda" hymn, 1500 B. C. See also pp. 113-17.

M. D. C. Crawford, The Heritage of Cotton (New York, 1924), pp. xv-xix.

it was not until the Industrial Revolution in England that the manufacture of cotton began to develop into the machine industry it is today. Many of the inventions upon which the present cotton textile industry is based came in rapid succession in the century following Wyatt's roller spinning frame of 1730. Notable among these inventions are the flying-shuttle by Kay, the spinning jenny by Hargreaves, the steam engine by Watt, the water power spinning frame by Arkwright, the spinning mule by Crompton, the power loom by Cartwright, the cotton gin by Whitney, and the ring spinning machine.³

The early spinning industry of the United States centered around Pawtucket and Providence, Rhode Island. The first successful mill was built at Pawtucket in 1790 by Samuel Slater, who came from England and brought with him a knowledge of the English textile industry.⁴ Slater's mill represented the beginning of the factory industry in the United States.⁵

The War of 1812 crippled the New England shipping industry. Attention was therefore directed to manufacturing as a substitute for the declining shipping industry. Heretofore the southern states had built up a manufacturing industry far beyond that of New England, but the invention of the cotton gin served as an important means of reversing this situation. It stimulated cotton growing and made it more profitable to grow cotton in the South; therefore manufacturing was put at a comparative disadvantage. It aided New England, which was seeking a substitute for its shipping industry, by providing an ample supply of raw cotton.⁶

Small local mills did develop in the South, but it was not until about 1880 that the southern textile industry of today had its beginning.⁷ These southern mills originally concentrated on coarse fabrics, but there has been a gradual tendency to make also the finer goods, until today Greenville, South Carolina rivals New Bedford, the fine-goods center of the American textile industry.⁸

By 1905 the mills in the cotton-growing states were using more raw cotton than the New England mills; by 1923 the value of their output exceeded that of the New England mills,¹⁰ and by

³ Crawford, op. cit., pp. xvii-xix. ⁴ Ibid., p. 144.

⁵ H. H. Maynard and W. C. Weidler, An Introduction to Business. New York, 1925.

⁶ Crawford, op. cit., p. 163.

⁷ Ibid., p. 164.

⁸ Ibid., p. 166.

⁹ United States Department of Commerce Yearbook, 1929, p. 497.

¹⁰ Ibid., 1926, p. 474.

1925 most of the spindles in the United States were in the cotton-growing states.¹¹ This rapid growth of the industry in the South has been at the expense of the New England industry, and some of it has been actual moving of New England mills to the South.

The cotton industry in Texas began in the last decade of the nineteenth century. Most of the mills are small local organizations that owe their existence more to local pride than to a calculated advantage. Nearness to raw materials and cheap labor are the other factors responsible for this development of a textile industry in Texas.

These mills were usually started on a small scale with local capital, often beginning with second-hand machinery. As a result of inexperienced management practically every mill in the state has been forced into a reorganization.¹² These mills have remained small and have devoted their attention for the most part to coarse fabrics.

For a number of years the cotton textile industry has sought to justify its low wages and poor labor conditions by its poor situation. The Committee for Elimination of Waste in Industry¹³ has lent support to this contention by the statement that 40 per cent of the waste in the textile industry was due to factors beyond the control of the industry itself, while only 16 per cent of the waste in the boot and shoe manufacturing industry, 14 per cent in the building industry, 10 per cent in the metal trades industry, 9 per cent in the men's clothing industry, and 9 per cent in the printing industry were attributable to outside factors.

With this unfavorable condition in the textile industry and its seeming helplessness, it seemed pertinent to consider whether it was using Scientific Management in attacking its problems, and if it was not already using the best in management theory, whether it could turn to better management for a solution to some of its problems.

¹¹ Ibid., 1929, p. 497.

¹² From statements made by various mill managers, in interviews, to the writer in 1928-29.

¹³ Federated American Engineering Societies, Waste in Industry (New York, 1921), p. 9.

The history of an outstandingly successful chain of cotton mills lends weight to the statement of the president of that chain. He insists that the cotton textile industry is very inefficiently managed and that it has much to gain by a thorough application of Scientific Management principles.¹⁴

¹⁴ Statement made to the writer on March 4, 1930 by H. P. Kendall, President of the Kendall Company.

See also: H. P. Kendall, "The Textile Industry Can Control Its Own Conditions," Textile World, LXXVII (April 12, 1930), p. 2172.

CHAPTER V

PURCHASING

The purchasing function of the mills studied was largely performed by the mill manager. True, at times he engaged one or a few cotton buyers to aid him in purchasing raw cotton, but these usually bought as they were told without discretionary powers.

Cotton is bought on length and the standard grades established by the Bureau of Agricultural Economics of the Department of Agriculture. These grades are:¹

- No. 1 Middling fair
- 2 Strict good middling
- 3 Good middling
 - Good middling yellow tinged
 - Good middling yellow stained
 - Good middling blue stained
- 4 Strict middling
 - Strict middling yellow tinged
 - Strict middling yellow stained
 - Strict middling blue stained
- 5 Middling
 - Middling yellow tinged
 - Middling yellow stained
 - Middling blue stained
- 6 Strict low middling
 - Strict low middling yellow tinged
- 7 Low middling
 - Low middling yellow tinged
- 8 Strict good ordinary
- 9 Good ordinary

In addition to these, the regular grades, there is a spotted and a gray classification. The first three grades are bright in color. The cotton is classed by touch and sight based upon the length and color of the staple. The ordinary cotton mill manager measures for length, but the expert cotton grader judges length by sight.

Samples classed as one-inch cotton by good staplers

¹United States Department of Agriculture, Bulletin 1445, p. 27.

(cotton graders) contained the following amounts and lengths of fibers:²

<u>Above 1"</u>	<u>1"</u>	<u>15/16"</u>	<u>7/8"</u>	<u>3/4"</u>	<u>Below 3/4"</u>
28%	39%	16%	8%	7%	2%
12	39	21	15	7	6
0	14	31	32	13	10
0	13	37	25	17	8

Further evidence of the shortcoming of the method of grading and the standards used is the emphasis placed upon the "feel" which enabled a sample of damp cotton to grade high, while that sample when dry was refused.³ Cotton is also often bought on the basis of a certain moisture content, 7.83 per cent being the accepted standard.⁴

Grade five, termed "middling," is the basic grade in terms of which all prices are quoted.⁵ It is the controlling factor in the price of the world's crop.

Ordinarily cotton is purchased on the basis of a sample part which is drawn from each end of the bale. Since the market for cotton is an international market, its price is not subject to much individual bargaining. Most of the cotton leaves the hands of the growers in the fall months. The small mills located in the growing section buy a large part of their cotton direct from the farmers or from the local gins. The mills in or near the market centers usually buy from the cotton merchants. It is customary for the mills to purchase stocks of raw cotton in excess of their immediate needs on the basis of their own appraisal of the market conditions.

The Price of Cotton

With an extremely sensitive cotton market⁶ and the practical necessity of buying raw cotton ahead of the immediate needs, the importance of right buying is quite evident. The sensitiveness of the cotton market has been often considered the curse of the cotton

² The Arkwrights, Inc., "Cotton Stapling and Carding," The Textile World, LXXI (June, 1927), 3767.

W. L. Balls, Studies in Quality of Cotton (London, 1921), p. 14.

³ Ibid., pp. 4, 9, 13.

⁴ Cotton Yearbook, published by Textile Mercury (Manchester, 1930), p. 167.

⁵ John A. Todd, The Worlds Cotton Crop (London, 1915), p.135.

⁶ Ibid., p. 365.

F. C. Mills, The Behavior of Prices (New York, 1927), pp. 199, 507.

manufacturing industry. The usual mill manager is confident of his ability to buy cotton advantageously, and therefore feeling that he can make a cent or two per pound through advantageous buying rather easily, he is not eager to tackle manufacturing cost reduction, which he has learned is a difficult problem. This situation in the New England mills has made the mill treasurer, who bought the cotton, the major officer. One of the ablest mill managers in the group surveyed stated that he was making his profits out of the advantageous purchasing of cotton rather than from the manufacturing.

In this variable market two courses are commonly followed. The mill may study the situation and attempt to purchase its cotton advantageously, or it may purchase its cotton according to its manufacturing needs and hedge to protect itself against fluctuations in the market, concentrating its attention on the manufacturing problems.

A full study of the cotton market has many ramifications, and certainly none of the mills observed attacked the problem with any degree of thoroughness. For predetermining the market, a statistical study has led to the conclusion that the supply of cotton and the general commodity price level, or items correlated with these, are probably the predominant factors in the price of cotton.⁷ From 1890 to 1925 the average cycle of cotton prices was 38.7 months, of which 23.3 months represented the average upgrade. The price variations during this period were considerable, averaging a rise from the previous low price of 114.7 per cent and an average fall from the previous high price of 42.2 per cent. The rises came 3.2 months after the upturn of the United States Department of Labor Wholesale Price Index, and the falls came 3.3 months after the same index.⁸ In studying the supply factor, it is possible to go back to the climatic conditions, the acreage planted, the expected yield, etc. The United States Department of Agriculture is spending about \$125,000 of its \$500,000 crop reporting budget on gathering cotton statistics. Reporters are located all over the cotton belt, as many as 6,000 being in Texas at one time. These men report directly to Washington, D. C. From these data government reports are issued in August, September, October, November, and December. The August report is of the acreage planted as of July 1. This is estimated in two ways: first, the local reporters obtain from various farmers estimates for the immediate locality,

⁷B. B. Smith, "Forecasting the Volume and Value of the Cotton Crop," Journal of the American Statistical Association, XXII (1927), 442-59.

⁸Mills, op. cit., p. 529.

of this year's acreage as a percentage of last year's acreage. Another method is to count by automobile and train the miles of cotton frontage on definite routes. Ginnings reports begin in October.⁹

This just touches on a few of the factors which influence the price of cotton, and it is with these factors that the cotton buyer must be concerned if he seeks to buy advantageously.

Most of the mills observed purchase cotton whenever their manufacturing needs demand and when they think the price is right. They have a general rule not to buy ahead for too many months. None of them study the market situation at all comprehensively.

Hedging

The general impression is that hedging does not offer the protection against losses from price fluctuations which the theory attributes to it. A hedge so combines a purchase and a sale that future price changes of the two will offset each other. If a mill purchases cotton today at 18¢ a pound, and the cloth that it normally manufactures is worth 32¢, there remains a 14-cent margin to cover the manufacturing costs and the profit to the mill. By the use of the hedge the mill can, in theory, assure itself this 14-cent margin even though it does not sell the cloth at 32¢. For example:

- | | | |
|---|--|------|
| 1 | Cotton bought at | 18¢ |
| 2 | To hedge, sell an equal amount of cotton today
on the futures market at | 18½¢ |
| 3 | Assume, three months later cloth is sold at | 30¢ |
| 4 | Very likely cotton has now fallen to | 16¢ |
| 5 | Cloth realized 30¢, cotton cost 18¢, leaving
a margin of | 12¢ |
| 6 | Can now buy cotton at 16¢ and turn it over on
the sale shown on line 2 above at 18½¢, mak-
ing a profit of 2½¢, minus ½¢ carrying
charges leaves a profit on the hedge of | 2¢ |
| 7 | Thus the actual margin of 12¢ (line 5) plus
the profit from the hedge (line 6) equals
the 14¢ margin. | |

The mill made on its hedge contract just what it lost on the operating contract, and had the market turned the other way, it would have lost on its hedging contract just what it would have made over and above the desired margin on the operating contract. The hedge operates similarly when the cloth is sold before

⁹ Data from H. H. Schutz, United States Department of Agriculture Statistician, Austin, Texas.

the cotton is purchased . With the assurance that the cotton price changes will not influence the mill margin, the management can devote its energies to the manufacturing problems rather than to worrying over the market. The market hazards are shifted, and the management has only the manufacturing hazards.

In actual practice, hedging does not operate so efficiently. The cotton cloth market does not regularly and immediately follow the raw cotton market, and the cotton spot market and the futures market do not always synchronize uniformly; therefore a price fluctuation is not always negated.

A study conducted by the Harvard University Bureau of Business Research took the actual history of a cotton mill that was using about 17,000 bales of cotton a year and computed the influence hedging would have had on this firm. They found that over a certain period of years, 1921-26, this mill would have lost over four hundred thousand dollars had it hedged completely. Their conclusion was that protective hedging for cotton mills was not possible now.¹⁰

Hedging has been termed both a pest¹¹ and also a boon of the cotton manufacturing industry.¹² A plan has been suggested by which the portion whereby the hedge makes up for an operating shortage is preserved, and the possibility of a hedge consuming any advantages of the market can be avoided. In this case a maximum price of cotton is determined for the crop year. When the actual price nears the maximum, no cotton should be carried unhedged because the probability is strong that the next change in the price of cotton will be downward. When the price nears the minimum, the probability is strong that the next change will be upward, therefore cotton may be carried safely without a hedge. This has been illustrated:¹³

Percentage of stock to hedge	When cotton sells at
100%	25¢ (the estimated maximum)
70	22¢
50	20¢
10	16¢
0	15¢ (estimated minimum)

¹⁰ A Study of Cotton Hedging in a Gray Goods Mill, Harvard University Bureau of Business Research Bulletin No. 49 (1921-26).

¹¹ Ward Thoron, "Hedging Viewed by Mill Treasurer," Textile World, LXXIV (November, 1928), 2469-70.

¹² S. T. Hubbard, Textile World, LXXIV (November, 1928), 2468.

¹³ George S. Harris, "A Cotton Hedging Plan that Avoids Speculative Extremes" Textile World, LXXIV (October, 1928), 1801.

G. W. Fooshe, "Hedging," Textile World, LXXIV, 173.

The difficulty in this plan is the difficulty of determining the maximum and minimum points of the probable market range, and the fact that the price may not vacillate uniformly throughout this predetermined range. Also the cotton spot, futures, and cloth markets do not move together. If properly used it is probably a valuable method of combining market with hedging to advantage.

The most complete and effective hedge is to buy the cotton and sell an equivalent amount of cloth as of the same time. This is the only sure way of guaranteeing that a certain operating margin will remain to the mill. The mills observed attempted to follow this method as much as possible, yet they commonly purchased far in excess of their needs during the fall months to take advantage of what they believed to be the low price which prevails during the marketing season. Most of them had considerable storage capacity of their own.

It is also common to hedge on basis. This is a shifting of the risk in the change of the price differential between the standard grade and some particular grade. Strict low middling is purchased at, say, a hundred points off May delivery; then if May delivery price of middling cotton turns out to be 18¢, this purchase of strict middling will be at 17¢.¹⁴ Guaranteeing a definite relationship to a base as variable as the price of middling cotton still leaves much to be desired in the way of risk shifting.

By and large the purchasing of raw cotton is done on little more than guesses on the future condition of the market, and hedging is regarded as a device for the cotton merchant and not for the spinner. The mill changes cotton into cloth, which does not follow the cotton price closely enough to give the needed protection. Specialized research is needed to determine the probable effectiveness of hedging in its various forms when applied to certain grades of cotton and certain finished goods into which this cotton is manufactured.

First and foremost the duty of the cotton buyer is to meet the manufacturing needs of the mill.¹⁵ He can meet these in several ways: He may gauge the market and buy at the lowest cotton cost possible, or he may buy at the market as the needs arise and attempt to shift the future price fluctuations. In the first case he may buy large quantities ahead of time when it is actually needed, while in the latter case he can operate on a production requirements budget.

The purchasing of repair parts and supplies is the other major function of the purchasing department. In the small mills

¹⁴ One hundred points equals one cent.

¹⁵ J. W. Roe, Materials and Their Handling, citing H. L. Gantt, p. 4.

it is also handled by the general manager. Among the supplies the large item is the sizing, a starch that is applied to the warp yarn to enable it to withstand the wear and strain of the weaving. The quantity required depends upon production and can therefore be predetermined, and its purchasing can be budgeted and scheduled.

CHAPTER VII

COTTON MILL OPERATIONS

The cotton as it usually comes to the mill is in bales 54 inches by 27 inches by 45 inches, containing about 480 pounds of fiber compressed to the density of approximately 22 pounds per cubic foot. Cotton which is shipped great distances, and especially that sent abroad, is compressed to a greater density and smaller size.

In the opening the metal retaining bands are cut, and the coarse jute covering is removed. Due to the way the cotton was fed into the press box when it was ginned, it may now be taken from the opened bale in layers. These layers are put on a slowly moving lattice, which is either built into the floor of the opening room or placed on top of the floor about a foot above the floor level. Several bales are usually opened at the same time, and layers taken from them in turn so that a layer of cotton from one bale is followed into the "bale-breaker" machine by a layer from another bale. This is done to equalize differences in the cotton. These layers, about six inches thick, enter the bale-breaker, which by a combing action separates the matted cotton into large lumps. Some of the dirt, burrs, and leaf particles fall away from the cotton, and the loose dust is drawn off by a fan.

From the bale-breaker these tufts are fed directly into the "opener," where they are beaten against grid bars to loosen the dust and other foreign matter, which is then removed by a suction fan. Here the cotton mass is further opened and the fibers separated from each other. The resulting smaller tufts are then delivered, usually through an air chute, to the picker room.

Picking

As the cotton comes into the picker room through an air pipe, it falls on a belt which carries it past the hoppers of the opening "pickers." As the weight of the cotton in the hopper is reduced to a certain point, a metal guide is automatically swung across the belt, brushing the cotton into this particular hopper. In this manner the proper amount of cotton is fed to each of the several opener pickers. These machines further loosen the tufts by beating them, thus removing more dirt and foreign matter. The resulting fleecy masses are then delivered through two rollers, which pack them into a continuous sheet called a "lap" about 48

inches in width. Forty-eight yards of this sheet are wound on an iron rod.

Four of these rolls are then fed simultaneously into the intermediate picker, one unrolled on top of the other. This combining is termed "doubling." A similar loosening and removing of foreign material is performed here. The resulting continuous lap is again wound upon a rod and fed in the same manner into the finishing picker, which repeats the process. The final picker lap standard weight, depending upon the particular mill, is usually from 14 to 16 ounces per yard. Each of these rolls contains 48 yards, and for accurate work these are weighed and re-run if they are not within a certain tolerance limit of standard. A yard of this lap containing $14\frac{1}{2}$ ounces of cotton will produce $7,612\frac{1}{2}$ yards of No. 10 yarn, well over four miles. If by mistake this lap were run heavy to the amount of half an ounce per yard, the loss in yarn would be $262\frac{1}{2}$ yards, since the yard of picker lap is stretched only $7,612\frac{1}{2}$ yards, regardless of errors in its weight.

Carding

The laps from the finisher picker are fed into the carding machine one at a time. The purpose of this machine is to remove as much as possible of the remaining foreign matter, to remove short, weak, and snarled fibers, and to disentangle and also arrange the fibers. This machine has a large cylinder containing from 500 to 750 tiny wires per square inch over all of its circumference. Going in an opposite direction are a series of flat plates also covered with tiny wires. The cotton is thus combed between these wires going in opposite directions. Brushing against this large cylinder is a smaller one which revolves more slowly so the cotton fibers are deposited on the wires of this doffing cylinder. A doffing comb oscillating rapidly picks the fibers from this doffing cylinder in the form of a very flimsy veil-like film of cotton 40 inches wide.

This film is put through a hole, a trumpet mouth, which is less than an inch in diameter. The film thus becomes the first continuous strand, a cord, commonly termed a "sliver," which is coiled into a can about a foot in diameter and four feet deep. This can holds about 12 pounds of sliver. This film as it is taken from the card is so thin that it sometimes breaks, or a part of it will break while the remainder still passes through the trumpet mouth forming a sliver which is underweight. The attendants must watch this and not let any underweight sliver remain in the can. A carding machine turns out about 15 pounds of cotton per hour.

Drawing

Six of these carded slivers are then fed, side by side, into the drawing machine, in which three sets of rollers, each succeeding pair revolving faster than the previous pair, stretch the

slivers so that the fibers slide along each other and become more nearly parallel. The slivers are then brought together, and when they are delivered from the last set of rollers they form a single sliver, which is the same size as each of the six original slivers and as long as all put together. The drawing frames have a front and back stop motion to stop the machinery when one of the six slivers taken in breaks or is overweight, or when the sliver coming out is very much under or overweight. This drawing process is usually repeated three times, with the result that the final drawn sliver is remarkably uniform at all points in weight and fiber content, and the fibers are nearly in parallel arrangement.

The finishing drawing sliver, which is the most regular strand in the mill, contains about 12,000 fibers at any point.¹ The following illustration emphasizes the value of the drawing process in obtaining a strand of uniform diameter.

The carded sliver with an average diameter of 12,000 fibers.	
5 x 12,000+6,000 (a weak sliver)	÷ 6 equals 11,000
5 x 12,000+11,000	÷ 6 equals 11,833
5 x 12,000+11,833	÷ 6 equals 11,972

If this weak spot is combined each time with a normal spot in the five other strands, at the end of the drawing process it will contain 11,972 fibers instead of the standard number, 12,000, not enough to make a material difference. Each drawing head delivers about 18 pounds of drawn sliver per hour.

Roving

Two of these drawn slivers are then fed into the roving machine, which again draws them out and gives them a slight twist and winds the cord upon a stick, called a bobbin. This, the "slubbing," winds about two pounds of cord (slubbing), which is about 2,520 feet, onto an eleven-inch bobbin. The draft or attenuation here is 4-5, and the spindle speed is about 600 revolutions per minute. This same process is repeated, giving more draft and more twist at each repetition.

The second stage in the roving is called the "intermediate roving." Here about 24 ounces, approximately 5,670 feet of roving, are wound onto a ten-inch bobbin. The draft is 4.5-5.5, and the spindle speed is about 800 revolutions per minute.

At the third stage, the "jack roving," about 14 ounces, approximately 8,820 feet of roving, are wound onto an eight-inch bobbin. The draft here is 5-6, and the spindle speed is about 1,100 revolutions per minute. For the finer yarns a fourth roving process is used. To obtain uniformity in the diameter of the

¹W. Lawrence Balls, Studies of Quality in Cotton (London, 1928), p. 127.

yarn much doubling is necessary. Four laps from the opener picker are doubled into the intermediate picker, from which four are again doubled into the finisher picker. Six carded slivers are doubled in drawing, which is repeated three times; then two slivers are combined at each of the three usual roving stages. The total doubling for untwisted yarns is therefore 27,648 ($4 \times 4 \times 6 \times 6 \times 6 \times 2 \times 2$). Twisted yarn is doubled twice that number, or 55,298 times.

Spinning

The final process in the production of yarn is the spinning, which is similar to the roving but which gives the cord more draft and more twist than even the last roving process. The yarn is here wound upon bobbins which revolve at a rate of speed up to 10,000 revolutions per minute, with a draft of $7-7\frac{1}{2}$. The yarn now has about 13 twists per inch.

The various grades of fineness of yarns is determined by a variation which usually takes place only after the drawing process in the coarse-goods mill. It merely consists of giving the cord more or less draft and twist at each of the roving stages and at the spinning stage. The yarn which is to be used as filling--often called weft (to run crosswise of the cloth)--is relatively loose and slightly twisted. It is ready for weaving as it leaves the spinning frame. The warp yarn (to run lengthwise of the cloth) is hard twisted and strong. It requires further preparation before it is ready for weaving.

Spooling

The spinning frame has wound the yarn on small bobbins. From these the warp yarn is transferred by a spooling machine to 6x5-inch spools. Each of the spools will receive about $1-1\frac{1}{16}$ pounds of yarn, which was on a number of bobbins. As one bobbin runs out, it is replaced by a full one, and the ends of the yarn are tied together by a small mechanical knotter, which the attendant carries in her hand.

Twisting

If the yarn is to be twisted (combined with a similar strand), a twisting frame takes the threads from two spools and twists them into one thread. The twist here is in the opposite direction to the twist of the yarn itself. The twisting frame puts the twisted yarn on bobbins, from which it is again transferred to spools.

Warping

The warping process transfers the yarn from these small spools to a larger spool called the warper beam. This beam is about a foot and a half in diameter and four feet long. First, about 500 spools are put on a frame (creel). The yarn from each of these spools is then fastened to the warper beam, onto which are

wound the 500 threads lying side by side. As the spools become empty they are replaced and the ends are again tied. Thus a warper beam will receive about 500 threads all of equal length, which may be up to 25,000 yards. When a thread breaks, the warper is stopped automatically.

Slashing

Next, several of these warper beams, depending upon the width of the cloth, are threaded through the slasher. Each warper beam contains about 500 threads side by side, but from the slasher 3,000 threads may be wound side by side upon the loom beam. As the yarn goes through the slasher it is submerged in a bath of hot starch and is then run over a large steam filled drum, which dries it before it is wound upon the loom beam. The purpose of the starch bath is to make the yarn stronger and more wear-resistant. In coarse-goods mills this starch bath is composed of a mixture of water, starch, fat, and some chemical preservative.

Drawing or Tying-in

The loom beam is next taken to the drawing-in or tying-in machine to prepare it for the weaving process. The interweaving process of the loom requires that certain threads be raised and certain ones lowered in order to form a diamond-shaped spread, a "shed," between which the shuttle may pass. To do this there is a frame, a "harness," which resembles a long narrow window frame, the sides of which are connected by many wires, each wire having a loop (needle eye) in the middle. Through one of these frames are threaded all the threads which are to be raised, and through another are passed the threads which are to be lowered simultaneously. Thus the lowering and raising of the frames forms the necessary shed. The threads may be drawn through these eyes in the wires by inserting a hook through the eye, catching the thread and pulling it through. Another method commonly used is to leave a short piece of cloth attached to the harness from the previous weaving. Now if, for example, it is desired to weave a cloth with a width of 2,800 threads, using the ordinary weave of having the filling pass over the threads and under them alternately, the harness as used for a former cloth of a similar number of threads is taken. This will consist of a strip of about 6 inches of cloth and about two feet of threads which had been used to make that cloth. These threads, which are still passed through two harnesses, 1,400 threads through each, are brushed out so that they lie parallel and then they are clamped down. Over these are laid the similarly brushed threads from the new loom beam, and a machine similar to a stitching machine ties the threads together, cutting off the ends. This loom beam is now ready for the loom. Each one of its threads is passed through an eye in one of the two harnesses; the loom beam is then attached to the loom, and the

harnesses are attached to the raising and lowering mechanism.

Weaving

In the weaving process the harnesses raise all the odd-numbered threads, for example, and lower all of the even-numbered ones; this leaves a diamond-shaped shed between the two sets of threads. Through this shed the shuttle containing a bobbin of filling yarn is passed, leaving a thread of filling yarn which has gone over every other thread and under the remaining ones. A reed then brushes this thread against the previously placed one. The relative position of the two harnesses is reversed, and the shuttle passes back through this new shed. Each pass of the shuttle is termed a "pick." The shuttle is given a starting impulse which slides it from one side of the loom to the other at an approximate speed of 40 feet per second.

An automatic bobbin-changing mechanism is usually attached to the loom. This consists of two centrally pivoted disks, which are about seven inches apart. Between these two disks all around the circumference are fastened filled bobbins. When yarn on the bobbin in the shuttle is nearly exhausted the empty bobbin is pushed out of the shuttle and a full bobbin is pushed into place from the circumference of this pair of disks. This prevents stoppage of a loom every time a bobbin is empty, but leaves some yarn on each bobbin. This is not only a loss of filling, but entails the extra labor of removing it before the bobbin can be put into the spinning frame to be filled again.

Every time the shuttle stops at the left hand side of the loom a small wire feeler pushes through an opening in the shuttle and touches the bobbin near its base. When the filling from the bobbin has been used to the extent that very little is left on the base, this wire feeler comes in further before it touches the now thin layer of yarn on the bobbin, and thereby trips the mechanism which replaces the nearly empty bobbin with a full one.

Rather ingenious mechanisms stop the loom when any thread breaks, either warp or filling. Small wires are hooked over the warp threads, and when one of these breaks the wire is pulled down by a spring tension and touches a mechanism which stops the loom. Every time the shuttle has passed, the filling thread is brushed back against the already woven cloth. When this is done a small prong brushes the thread near the shuttle and trips a wire hook. When the thread is broken or the shuttle does not reach its destination, this wire hook will not be tripped and the loom is stopped instantly.

For weaving fancy goods, several shuttles are often used in the same loom at the same time, each containing a different kind of yarn. Another feature of a fancy-goods mill is an arrangement whereby any thread may be raised or lowered in forming the shed,

regardless of other threads. This makes it possible to work out various weave patterns. In the Jacquard loom the selection of the threads which are to be raised and lowered is governed by a pattern punched in paper much like the paper roll used on a player piano. This permits a wide variety. In the Dobby loom the selection is controlled by raised points on a small metal bar. These bars can be attached to endless chains and the patterns will repeat themselves again and again.

As the cloth is woven it is wrapped onto a bar in sixty-foot lengths, which are termed "cuts." From these bars it is wrapped onto other bars, after it has passed over an inspecting frame which consists merely of a frame with a glass in it and lights under the glass. As the cloth is drawn over this frame, an inspector stops the winding when he sees a defective spot, which he either repairs or marks so that the piece may be classed as defective. Next the cloth is passed through the calendering machine, which smooths out the wrinkles. Finally it is folded and baled ready for shipment.

CHAPTER VIII

PRODUCTION REQUISITES

The production requisites fall under five different heads: the raw material, which is to be fabricated or changed in some way; the machinery, which is to change this raw material into its proper form; the power machinery to drive this operating machinery; the human aid and direction to control and operate these three factors as a coordinated unit; and the buildings to house these factors and to facilitate their proper operation.

Raw Materials

Raw cotton (gossypium) constitutes the raw material of a cotton mill. It is grown on a plant that reaches a height of approximately four feet, bears about a dozen pods or bolls, each one of which contains about a dozen seeds, each of which is covered by about ten thousand hairs.¹ During the growing season of from forty to eighty days, these fibers develop into round hollow hairs filled with fluid. Daily growth rings in the longitudinal cross-section of the hair resemble the yearly growth rings of a tree. After the boll has opened the cotton matures, the inside fluid evaporates, and the fiber becomes ellipsoid and spiral. Of these spirals 94 per cent start toward the left, but they reverse themselves about fifty times in the length of the fiber.² The ginning process tears the fibers from the seed. The mature fibers of the American-grown cotton vary in length from less than one-quarter of an inch to an inch and three-quarters, with the bulk of the American crop being from fifteen-sixteenths to an inch in length.

Slipperiness, fineness, strength, and length are the most important properties of the fiber. These, together with color, are taken into consideration by the buyer. Length, however, and to some extent color are the only factors which are judged at all objectively. Length is usually estimated, and color is merely judged by sight. The proper measurement of color must take into consideration hue, brilliance, and chroma, and must be determined spectrophotometrically.³ In careful laboratory studies a number of

¹These are approximate figures. ²Balls, op. cit., p. 21.

³Robert W. Webb and Wanda K. Farr, "Progress in Cotton Fiber Study," Textile World, Vol. LXXVII, No. 15, pp. 2173-79.

tests have been used, some of which are length, weight, ribbon width (meaning the diameter at the middle of the fiber), wall thickness, cell diameter, specific gravity, convolutions, hair strength, stress-strain, resistance, internal structure, lateral stiffness, surface coefficient of mutual friction, bacterial damage, photo-chemical or other weathering effects, wax content, ash content, and X-ray diffraction.⁴

Ordinarily cotton is used just as it comes from the field. Recently, however, a successful oil treating experiment has been conducted. Five ounces of oil per hundred pounds of cotton made for better working, reduced breakage, total waste, and also the lint content of the air within the mill.⁵

In most instances the coarse-goods mills re-work and use most of the waste, selling the remainder for mattress-making, etc. The starched yarn waste is often sold for mop filling.

The approximate percentage of waste is:

Opener picker	3	-	$4\frac{1}{2}$	per cent
Intermediate picker	$1\frac{1}{4}$	-	2	" "
Finisher	1	-	$1\frac{1}{4}$	" "
Card	4	-	$5\frac{1}{2}$	" "
Drawing	$\frac{3}{4}$	-	$1\frac{1}{4}$	" "
Roving	$1\frac{1}{2}$	-	2	" "
Spinning	$1\frac{1}{2}$	-	2	" "
	13	-	$18\frac{1}{2}$	per cent ⁶

The Equipment: Operating

The operating machinery working on the product must be considered in relation to the product itself and the operations which are to be performed. If the work is varied it is necessary to determine whether a separate specialized machine should be provided for each variation or whether only one kind of machine with various adjustments should be provided. A pair of pliers may be the most useful single tool which a mechanic can carry, although for each of a dozen different jobs some special tool may be much more suited. As the variety of work demanded of one machine is narrowed, that machine can be more and more adapted to the special

⁴W. L. Balls, Handbook of Spinning Tests for Cotton Growers (New York: Macmillan, 1921), pp. 50-52.

⁵A. R. Marley, "Oil-Treated vs. Untreated Carded Cotton," Textile World, Vol. LXXVII, No. 12, pp. 1750-52.

⁶Cotton Yearbook (1930), published by the Textile Mercury, Manchester, p. 183.

W. B. Cornell, Industrial Organization and Management (New York: Ronald Press, 1928), p. 61.

needs of the work.

Flexibility of equipment.-- An automatic machine which turns out only one product in only one way usually does it at a smaller cost per unit than a general machine. Since the labor cost is often large in proportion to the total cost, it is economical to spend thousands of dollars on improved and more automatic machinery to reduce the labor costs of operating it.⁷

Most of the cotton mill machinery permits some adjustment. The pickers may be adjusted to turn out a different weight lap; the cards may be adjusted to turn out a different weight lap; the drawing machines may be adjusted for more or less draft; and the draft and twist both may be adjusted on the slubbers and also on the spinning frames. Quite a variation is possible in the number of threads wound upon a warper beam, passed through the slasher, and used on the loom. The bale-breaking machinery may be adjusted for the length of the fiber only within a narrow range. The same spinning frame may be adjusted to spin fine or coarse yarn, but only so within a narrow limit. Most of the adjustments in a cotton mill do not require much time and do not interfere with the automaticity of the machines.

Selecting machinery.--The choice of machinery is usually made by the mill manager together with the mill superintendent. The number of manufacturers supplying the mills is often relatively small. One mill, for example, obtained about 85 per cent of its equipment from two sources. These manufacturers stand ready to give advice on the proper kind of machinery and its use, but recent improvements and inventions are comparatively unimportant and meager.⁸ There is still much room for study on the proper operating speed for the various machines.

Industrial engineers, some of whom specialize on textile problems, are also available sources for advice. At best, these specialists represent the accumulated knowledge, thought, and experience in the field, and are in a position to give valuable advice.

⁷See L. P. Alford, Laws of Management (New York, 1928), p. 96; Paul M. Atkins, Factory Management (New York, 1926), pp. 48-50; J. A. Shepard and G. F. Hageman, "Formulas for Computing the Economics of Labor Saving Equipment," Mech. Eng., XLVII (1925), pp. 403-408.

⁸H. P. Kendall, "A Decade's Development in Scientific Management," Taylor Society Bulletin, Vol. IX, No. 2 (1924), p. 56: "The history of progress in cotton mill machinery gives 1897 as the last time when any improvement of consequence in textile machinery was made."

Machinery Balance

Cotton manufacturing resembles closely what is commonly termed integrative production. This means that the product progresses through the successive stages in a continuous stream, usually mechanically impelled and correctly timed.⁹ This regular flow magnifies the necessity of proper machinery arrangement, layout, and uniform output capacity. The smallest output capacity in this chain limits the output of the whole, and excessive output capacity at any stage is largely wasted.¹⁰

With machinery manufactured in separate units, maintaining uniform output capacity is a particularly difficult problem in a cotton mill because of the constant change in the product. Practically every mill manufactures several fabrics, and it is only at one of these, if at all, that the mill is in perfect balance. As soon as it produces a different fabric, certain machinery will not be able to absorb all of the output of the previous machines, and this machinery must work overtime, or the other machinery must work short hours, or some fabric will have to be produced which will unbalance the mill correspondingly in an opposite direction.

When a mill balanced at 8-ounce duck changes to 12-ounce duck, it will find that from the drawing processes on its machinery will not be kept busy. Up through the drawing process the output is standard regardless of the final product. If the product to be made is to weigh twelve ounces to the yard instead of eight, it will be made out of heavier yarns. To make a heavy yarn requires less draft and twist than is required to make a light yarn; therefore with the same spindles, much more of this heavy yarn can be produced in a day than can be produced of the finer yarn.¹¹ In

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John H. Van Deventer, "Ford Principles and Practice at River Rouge," Industrial Management, Vol. 64, No. 3, p. 131;

T. P. Cates, "Can the Textile Industry Be Fordized?" Textile World, LXVIII (August, 1925), 907-909.

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See Edward D. Jones, The Administration of Industrial Enterprises (New York, 1916), pp. 60-70; Dexter Kimball, Principles of Industrial Organization (New York, 1925), pp. 76-81, 84-86; Charles Day, Industrial Plants (New York: Engineering Magazine Co., 1918), Third Edition, pp. 109-110.

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In one of the mills studied the spindle output per hour of number 12 yarn was .06 pounds, while the output of the coarse number 4 yarn was .2 pounds. Number 12 yarn, or 12-hank yarn, means a yarn of which 12 strands, each 840 yards in length, are required to equal a pound. Number 8 yarn is heavier, and 8 strands, each 840 yards in length, equal a pound.

the weaving process it also will require less time to produce a yard if the yarn is coarse than it will if it is fine. If the mill were to change permanently to the 12-ounce duck, it could balance itself by adding more equipment to the stages up through the drawing, but normally the mill will produce 6-, 8-, 10-, 12-, or 14-ounce material just as its demand requires. With this changing variety of product, the mill balance is a continuing problem, which requires producing enough under the mill balance figure to compensate for that being produced above that figure, or it requires overtime or short time at some stages.

To illustrate:

Cotton			Through Drawing		Spinning		Weaving		Product
lbs.	lbs.	hours	lbs.	hours	lbs.	hours	lbs.	hours	
10,000*	10,000*	10*	10,000*	10*	10,000*	10*	10,000*	10*	8-oz. duck*
10,000	10,000	10	4,000	5	4,000	5	4,000	5	6-oz. duck
			3,000	3	3,000	3	3,000	3	8-oz. duck
			2,000	1½	2,000	1½	2,000	1½	10-oz. duck
			1,000	½	1,000	½	1,000	½	12-oz. duck

*The mill is here balanced at 8-ounce duck.

According to the foregoing illustration, the problem confronting the manager when he has obtained a certain order for 6-ounce cloth, is that of obtaining orders for something coarser than the 8-ounce cloth on which the mill is balanced to compensate for the unbalancing of the 6-ounce order. It is a problem requiring constant effort, and it is usually settled on data that are ridiculously inadequate. Few, if any, mill managers know the amount of extra cost in the form of idle equipment incurred by an unbalancing order; and further they do not know how low they can quote on an order that will fit into their operating schedule in such a way as to bring the mill into balance again.

Another problem in this connection is the cost of changing from one product to another. The cotton mill machinery adjustment required for such a change is usually not difficult nor time-consuming, but it is made often. Only in the files of one of the leading cotton mill accountants of the country was anything found on this subject. This was a study trying to determine the economical size of an order.¹²

¹² Ralph C. Davis, "Method of Finding Minimum Cost Quantity in Manufacturing," Management and Administration, IX (April, 1925), p. 352.

Equipment Layout

In the location of machinery such factors as the weight of the machinery, the rigidity of the foundation it requires, the noise, the dust and other undesirable features connected with it may require special consideration.¹³

In the cotton textile mill these unusual factors seldom require special consideration, since none of them is particularly outstanding.

The sequence of location is largely dependent upon the processes themselves. The minimum movement of material has been given as an important factor in layout.¹⁴ It is customary to have the bale-breaking and opening processes on the ground floor, often in a separate building. This is mainly due to the fact that the moving of the cotton bales is thereby reduced. From here the tufts of cotton are blown through a pipe into the picking machines, which are usually on the second floor. The placing of machinery then usually follows the sequence of manufacturing--the three stages of picking in sequence, then the cards, then the drawing frames, then the three stages of roving. The break is often made here by taking the slubbing downstairs by elevator to the spinning process, then the warping, slashing, tying-in, and weaving processes in order. Thus the product follows a regular course. When the machinery has been placed according to a predetermined plan, the operations should be studied carefully to discover any flaws or faults in the original plan or any new developments which may make rearrangement necessary, or at least desirable.¹⁵

In practically all mills, and especially those in the drier climates, the atmosphere within the mill must be conditioned artificially. The cotton is worked much more readily if the atmos-

¹³ C. D. Babcock, "Building Tractors under Scientific Management," Management and Administration, Vol. VIII, No. 1 (1924), p.19; Ralph C. Davis, op. cit., p. 352; John W. Hallock, Production Planning (New York, 1929), p. 100.

¹⁴ See L. P. Alford, Laws of Management (New York, 1928), p. 153; Dexter Kimball, Principles of Industrial Organization (New York, 1925), p. 76; A. F. Denham, "Frames Produced Automatically in Two-Hour Cycle," Automotive Industries, Vol. LVIII, No. 11 (March, 1928), p. 437.

¹⁵ See Harold T. Moore, "Influence of Plant Design on Plant Efficiency," Mech. Eng. Vol. XLVII, No. 11a, pp. 1059-60; A. G. Anderson, Industrial Engineering and Factory Management (New York, 1928), p. 124.

phere is highly humid. This humidification is obtained by spraying water vapor into the air. Much study is still needed to determine the exact humidity required at each of the processes. The common method is to have spraying nozzles located throughout the plant, and in Texas mills the usual response to a question concerning conditioning is, "Humidity; you can't get too much of it." A factor which impresses the casual visitor to a cotton mill is the oppressiveness of the heat and especially the humidity within the mill. Another method of conditioning the atmosphere is to have forced ventilation, cleaning the air and humidifying it as it is taken in. In addition to this, it is advisable to have humidifiers at special points where greater humidity is desired.

An English authority states: "A Humidifier should give just the right degree of humidity to the atmosphere without involving the risk of drops falling onto the goods or machines below, and should at the same time act as a ventilator."¹⁶ The cotton ordinarily averages about $9\frac{1}{2}$ per cent moisture when it is taken into the mill. It loses over half of this by the time it is ready for the carding process, due probably to the fanning effect of the fast-moving open machinery. With this low moisture content the tendency to curl during carding is reduced. A humidity of about 50 per cent during the carding, 53 per cent during the roving, 55 per cent during the spinning, 68 per cent during the warping, and 74 per cent during the weaving brings the moisture content back to where it was when the cotton was taken into the mill. A humidity of 62 per cent in the cloth room holds the cloth weight at about the point at which it left the weave room.¹⁷

Power.—The function of the power machinery is to drive the operating machinery and any other auxiliary machinery. In the cotton mill this means the operating machinery, the ventilation and humidification machinery. Since steam is required in the slashing (starching) process, a boiler must be provided. Usually this boiler furnishes steam for the slasher and heats the building during cold weather, while electricity is ordinarily used to provide the necessary power.

The southern mills, where steam for heating is required for only a small part of the year, are confronted with the problem of whether to have one large boiler to take care of the slashing and heating, or whether to have a boiler for each, and thus have only the operating expense on a small boiler when heat is not needed.

¹⁶ Cotton Yearbook (1930), p. 598.

¹⁷ See Cotton Mill Handbook (New York, 1922), published by the Textile World, pp. 23-28.

Some of the mills in the older mill centers use steam power, but the newer mills practically all use electric power. The mills studied found it desirable to use electric power which they purchased. It is doubtful if the power problem is settled on the basis of verifiable data in any but a very few cases. Engineering firms and equipment manufacturers concerned give figures on comparative costs of making or buying power, of electric, steam, or internal combustion engine power, etc. But these data are often not reliable and are practically never based upon the exact conditions of the case.

Power distribution.--Power may be distributed from one or a few central sources through overhead shafting, or it may be furnished by a motor for each machine. The group drive system, which is merely a modification of the central power distribution system, has one motor driving several machines. This is advisable where machines that can be placed close together are normally either run or left idle as a unit, and where the plant transportation does not require that there be no obstructing overhead shafting. The group drive system is used extensively in textile mills, and often it costs only one-third as much as individual drives.¹⁸ Large motors and flywheels stabilize the load and conserve power. Many times certain machinery makes varying power demands during the day, and when these peak demands come at different times, a group drive system will require less total horse-power capacity than would the unit drive system. Actually, by a change to a group drive from a unit drive system, the required horse-power capacity may often be reduced as much as 80 per cent.

The unit drive system, with its one motor per machine, eliminates overhead shafting, with the friction losses and belts that go with it. This removes obstructions to overhead conveyances and to lighting. It also permits locating machines where they are needed regardless of the limitation of source of power, and it saves operating large motors and much shafting when only one or a few machines are operated. In addition it permits portable machines. A particular application of this feature is the new tying-in machine that is being used in some of the mills. This machine can be wheeled to the loom where the new threads are

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See Robert W. Drake, "When to Use Group and Individual Drives," Industrial Engineering, Vol. LXXXII, No. 2, pp. 56-60; Cornell, op. cit., pp. 368-408; David Moffat Myers, "Make Power, Buy Power - Which?" Factory and Industrial Management, Vol. LXXVI, No. 6 (December, 1928), p. 1096; A. G. Anderson, Industrial Engineering and Factory Management (New York, 1928), pp. 205-207.

tied onto those of an old piece without removing the old piece from the loom.

A cotton mill usually makes use of both of these methods of securing power. One engineer recommends that unit drives be used for the openers, pickers, drawing frames, spinning frames, spooling frames, looms, and humidifiers; and that group drives be used for cards, roving, spooling, warping, and slashing.¹⁹ Group drives were used to the limit in most of the mills observed. The tying-in machines, which usually ran very intermittently, were often driven separately, as was also the humidifier, which required the production of compressed air, demanded intermittent operation and much power for short duration.

Buildings.-- The function of the building is to house the machinery and equipment in such a way that operations will best be facilitated.²⁰ This is a twofold demand: first, that it furnish something to which to fasten and attach machinery and equipment, such as foundations, floors, walls, and overhead beams; second, that it cover and protect the equipment from the elements. Where heavy machinery is to be put on the second floor, the construction of the building must possess features of rigidity that would otherwise not be demanded. Overhead shafting will also demand a certain rigidity. The common practice of fastening electric motors to the ceiling will also demand a certain amount of rigidity.

Construction problems of stresses and strains, together with problems of cost of construction, often enter and favor a building that does not just cover the machinery and the processes, wherever they may be located. Thus most of the buildings are either oblong, U-, H-, L-, E-, or T-shaped. The textile industry does not furnish examples of a building so uniquely constructed for the particular situation as the railroad roundhouse; neither does the situation demand so insistently such a unique building.

Another feature in determining the proper type of construction is lighting. So-called illuminating engineering is still in its infancy. The reinforced concrete structure of the newer cotton mills, with its exceptionally large amount of window space, gives evidence of the attention paid to this feature both from the standpoint of the better quality of the work and the cost of artificial lighting.²¹

¹⁹ R. G. Macy, "The Construction and Costs of Southern Cotton Mills and Equipment," Management and Administration, Vol. VIII, No. 1 (July, 1924), p. 47.

²⁰ Denham, op. cit., p. 437.

²¹ Cornell, op. cit., pp. 91-95.

Other factors to be considered are the economy of construction and the economy of use.

The usual type of construction found was an oblong two-story brick building. Most of these buildings were built about thirty years ago and therefore do not have the window space which the more modern mills have.

Whether to build a two-story or a one-story building depends upon the cost of the site, the relative lighting of the two buildings, the relative cost of construction, and the cost of operation. Moving material up is costly, and sometimes moving it down is also costly. A single lift to the top of a building is usually cheaper than would be a series of lifts of an equal aggregate height. In the small mills the only lift was the cotton from the opening process, which was blown into the picker room on the second floor.

Provision for future expansion must also be kept in mind. A certain study revealed that out of 132 plants, the managers of 89 stated that they believed their chief mistake in designing the plant they were using was that they had neglected to provide for future expansion.²²

The tremendous shift of the cotton textile industry to the South is a matter of general knowledge. The causes usually assigned for the shift are nearness to the raw cotton, climate, and cheaper labor. The nearness-to-raw-materials argument is considerably weakened by the distance from the finished goods market;²⁴ the advantages of climate have usually proved of little value; and the labor cost argument alone remains as probably the most important explanation. For the long run even this advantage may be removed.

The cost of construction may also have had some bearing in bringing new construction to the cotton-growing states.²⁵ It is like all the others--just one of the many factors which must be evaluated in monetary terms in order to determine the spot where

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Henry T. Noyes, "Planning for a New Manufacturing Plant," Annals of the American Academy of Political and Social Science, Vol. LXXXV, No. 174 (September, 1919), pp. 41-56.

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Harrison S. Colburn, "Labor Considerations in Plant Location," Manufacturing Industries, Vol. XIII, No. 4 (April, 1927), 261.

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Harvard University Bureau of Business Research, Bulletin 56, "Distribution of Textiles."

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Ralph G. Macy, "The Construction and Costs of Southern Cotton Mills and Equipment," Management and Administration, Vol. VIII, No. 1 (July, 1924), p. 47.

the total production and distribution costs are at a minimum. Some of the more important factors which must be considered in addition to those already mentioned are the climate, the power, the accessibility to the markets from the standpoint of time as well as cost, taxation, etc.

Piquet, in a study of a hundred leading industries made some years ago, disclosed the fact that in almost all instances the plant had been located in the founder's home town.²⁶ This accounts almost exclusively for the location of the mills included in this study.

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John A. Piquet, "Scientific versus Haphazard Plant Location," Industrial Management, Vol. LXIX, No. 6 (June, 1925).

CHAPTER IX

STANDARDIZATION

A standard is a "unit of reference," a "basis of comparison," a "model."¹ The first and most important purpose of standards is to promote efficiency in the use of energy and materials;² the second purpose is to serve as a means of controlling the use of energy and materials. The second really finds its justification in the contribution it makes to the first purpose. Standardization is at the very basis of sound management.³

Standards should be determined or approved upon the recommendation of technical experts, by those responsible for the operation of the business unit in its various phases. Standards objectify and clarify those conditions and methods that have been accepted as best by those who presumably are not only qualified but also in a position to direct effort in the proper direction. In their model establishing aspect they are means by which executives can project themselves down through the structure of the business unit, and they are also the means by which results can be viewed in relation to the acceptable, and can be segregated into those who are in compliance and those who are at variance with the standard. They constitute an easy way of segregating quickly that which demands corrective attention from that which is already acceptable. Thus standards aid in converging the executive attention upon the weak spots. Matters that are already acceptable need only a recognition of that fact.

Standardization has long received attention, but it is only

¹ See Oliver Sheldon, Philosophy of Management (New York: Prentice-Hall, 1924), p. 212; Dexter Kimball, Principles of Industrial Administration (New York: McGraw-Hill, 1925), p. 41; H. K. Hathaway, "Standards," Bulletin of the Taylor Society, Vol. XII, No. 5, p. 491.

² C. D. Stone, "Standardization and Progress," Electrical Journal, May, 1926, p. 208.

³ John Gaillard, "Standardization," Bull. Taylor Soc., Vol. XV, No. 2, p. 118.

comparatively recently that it has been attacked vigorously.⁴ In the United States the engineering societies were the first to give special attention to the subject. One of the first definite moves was the appointment by the American Society of Mechanical Engineering, of a Standardization Committee on Pipe and Pipe Threads in 1885.⁵ The American Institute of Electrical Engineering followed with a special committee in 1889, and in that same year the American Society for Testing Materials was formed. From an international standpoint, standardization is being sponsored most vigorously by such organizations as the Department of Commerce of the United States, the British Engineering Standards Association and the Reichskuratorium of Germany.⁶

Much of the work on standardization, especially of our Department of Commerce, has been an attempt to reduce the number of sizes, forms, shapes, weights, etc., without hampering the use of the article unduly. The elimination of duplicates or near duplicates requires a careful study into the needs for the varieties on the market, and how these needs might be met by the smallest number of varieties possible. The engineering societies have emphasized the determination of what is best adapted to the needs and have considered the reduction in varieties as merely a by-product of finding the best.

Standardization requires a determination of the needs of the situation, then of the means of supplying those needs. These two must then be evaluated together to determine the best way of meeting the needs. After the standard of either condition or method has been determined, it should be formulated accurately, definitely, and completely, and conveyed to those who are to use it. The full import of the standard together with its use should be taught the users, and a system of inspection should insure compliance with the standard and measure its results.

The application of standards has its limitations. In making a certain cloth, the weight, threads, count, twist, sizing, loading, terminology, and matters of a similar nature all are engineering questions and are proper subjects of standardization.

⁴L. P. Alford, "The Fundamentals of Management Applied to Industrial Enterprises," Mechanical Engineering, LI (October, 1929), 745-46.

⁵"Engineering and Industrial Standardization," ibid., XLIII (February, 1929), 146.

National Industrial Conference Board, Industrial Standardization (New York, 1929), pp. 70, 124, 65.

⁶L. Urwick, The Meaning of Rationalization (London, 1929), p. 119.

In marketing, the tastes and style wishes of the probable consumers are matters of human preference and are usually not regarded as proper subjects for standardization. It is entirely probable that these latter matters will some day be brought within the field of standardization.

Standards in business have been grouped, for example, under the heads of job, individual, management, tools and product;⁷ or under equipment, materials, methods, accomplishments, and product.⁸ Standardization is here discussed under the two heads of physical and human factors.

Physical--Materials and Supplies Standards

The standards used in buying raw cotton do not constitute a true measure of the desirability of cotton for manufacturing purposes. In the main, however, the mills are satisfied with them. The exact qualities required of cotton to be manufactured into certain cloths is not yet known. It is known that $1\frac{1}{2}$ -inch cotton will make a yarn three times as strong as $\frac{1}{2}$ -inch cotton when both are spun to the best advantage, and that fineness is even more important than length of fiber.⁹

In addition to the needs for more study to determine the important characteristics of cotton and their influence upon the working of the cotton and the final product, there should also be more study of the supplies used in the mill. These are largely in the form of starch, tallow, zinc chloride, coal, and water. No research on these matters was found in the mills observed. The cost is prohibitive if the mills are to undertake this research individually. The national Cotton Textile Institute is beginning to undertake research from which all mills may benefit at a minimum cost.

Physical--Equipment Standards

Time and motion studies, though usually considered only in terms of persons, also apply to machines. The motion aspect of machines is largely a technical engineering problem, but the time aspect is quite susceptible to variation, and demands standardization. Machines as well as men have a point of optimum output, which must be determined by a study of speeds, feeds, uni-

⁷Alford, Mechanical Engineering, LI (October, 1929), 744.

⁸H. K. Hathaway, "Standards," Bulletin of the Taylor Society, XII (October, 1927), 491.

⁹Balls, Studies of Quality in Cotton, pp. 157, 165.

Kendall, "Scientific Management in a Textile Business," Bulletin of the Taylor Society, XII (December, 1927), 523.

Richard G. Knowland, "The Slashing of Cotton Warps," Textile World, LXXIV (November 3, 1928), 94.

formity of raw material, lubricating, cleaning and repairing, the output, and the people who are to operate the machine. Manufacturers of machinery usually provide some of this information, but it is often unreliable.

Standard settings are also important. If the opening machines are not set properly the fibers may be subjected to such a vigorous beating that many of them break, and the waste is excessive. This is also true of the picking machinery and the cards.¹⁰ The drawing machine rollers must be spaced properly, taking into consideration the length of the cotton fibers. If one set of rollers grasps the fibers before the previous set has released them, the greater speed of the second set of rollers will tear the fibers. If the sets of rollers are too far apart the sliver will be drawn unevenly, becoming too thin and too thick alternately. One of the purposes of the slubbing and spinning is to give the thread enough twist to keep it from pulling apart; so there should be standards of twist as well as of draft, both being considered in terms of each other and also of the cotton and the yarn desired.

In some cases the standard speeds are readily determined, while in others they present difficult problems. It is often a question of finding and determining the limiting factor, and establishing the speed limits in relation to it. For example, with the spindles revolving at speeds of about 10,000 revolutions per minute, it is quite likely that the centrifugal force which the threads can withstand is the limiting factor. The amount of strain that the thread can stand is the limiting factor at many stages in the mill. Warping, for example, permits much greater speeds than have been used without harming the yarn.¹¹ The frictional cohesion between the threads is also the limiting factor at the drawing and the spooling stages. In the drawing the hairs are to slide along each other uniformly, which requires slow speed; in the weaving they are not to slide along each other at all. The speed of the slasher is limited by the time required for drying the yarn, which in turn is conditioned by the maximum temperature which may be used in the steam-filled drum and the size of that drum. The cohesion of the fibers does not enter as an important factor here. In weaving, the speed of the shuttle is the limiting factor.

A certain mill was collecting its production data under a handicap because it does not have just one standard size spinning frame. The hank clock recorded the output per spindle on the frame, but this meant a different output depending upon the size

¹⁰"Working Out Fundamental Methods," Southern Textile Bulletin (October 25, 1928), p. 9.

¹¹"High Speed Warping Method," Textile World, LXXIV (December 15, 1928), 24.

of the spinning frame.

Production may be viewed as demanding the maintenance and the use of operating capacity. Maintaining operating capacity requires the maintenance of a qualified labor force and is the function of the personnel department. It requires such advance planning as the varying output may demand. Access to the sources of labor, methods of selection, induction into the plant, training, and stimulation are the important elements that may be standardized.

Maintaining the equipment in working order is a matter of repair and upkeep. Experience has proved that it is better to consider repairing as a preventive measure rather than a corrective one.¹² Replacing a part which has not yet ceased functioning may lose some service value and require inspection; but the alternative implies inefficient operation during the final period of the machine's usefulness, the inopportune time of the breakdown, and the possibility of damage to other machinery when the break occurs. Of course even with the most rigid attention to repairs and replacements, breakdowns will occur--usually as the result of failure to maintain standard conditions in the product or in operation. Having adopted the policy that repairs and replacements are to be considered preventive rather than corrective measures, two courses are ordinarily open, both of which are generally used.

Repairs and replacements may be scheduled definitely, or inspection may be scheduled, with the repairing or replacing dependent upon the findings of those inspections. The latter method is the more common. Here the inspection of every piece of equipment is performed according to a regular predetermined schedule, and the findings of the inspection are permanently recorded together with the recommendations of the inspector. In addition to this the cleaning and oiling and other attention which the machinery requires should be scheduled and performed accordingly.

The predetermined servicing and inspection schedules should be based upon expert engineering knowledge of the particular situation. Very dry or oil-treated cotton may require different cleaning and oiling schedules. With the general knowledge of lubricating requirements possessed by the ordinary machine man, it is entirely likely that a lubricating schedule determined by experts would not only reduce the lubricating costs but also the wear and tear on the machinery.

After standardized conditions of use have prevailed long enough it may be desirable to utilize this experience in establish-

¹² Alford, Laws of Management, p. 214.

Kendall, Bulletin of the Taylor Society, XII (December, 1927), 523.

ing repair schedules which are independent of the inspections unless unusual wear develops. This relieves the inspector from making a decision of whether or not to repair or replace. He is often poorly equipped to make such a decision. Such a schedule may reduce the cessation of regular operations to a minimum by utilizing shutdown periods, vacations, and after-hours for repairing and replacing worn parts and equipment. Anything that requires attention at a time other than the scheduled time should be disclosed by the regular inspection, which still gives some opportunity of attending to the matter at some time more suitable than the one when the break might occur. With repairs and replacements predetermined and scheduled for regular performance, and inspection to determine those needs that must be met before the scheduled time, there will remain only the extraordinary cases to disrupt operation and interfere with the plans and delivery promises of the management.

Such a plan of scheduling repairs and replacements and checking up through inspection has been eminently successful in a chain of cotton mills which have been definitely committed to this policy for some years.¹³

Inspection may be of two kinds: the regular cursory examination, and the less frequent complete and thorough examination which disassembles the machines. The cursory examination may include such matters as the speed of the machines, the belt tension, the machine adjustments of various kinds, and the quantity of output. In the opening machinery the beaters are adjustable. The vibrations and the wear and tear may change these adjustments and make it impossible to maintain standard cleaning conditions, unless this adjustment is checked and corrected. The wire-covered surface of the cards requires frequent inspection to determine the condition of the wire points, which become frayed, blunt, or bent. They must be ground periodically to give them a flat even surface. The two wire surfaces of the card are close together and revolve in opposite directions; hence their adjustment is very important. The thin film of cotton fibers which is taken from the card requires accurate adjustments of speeds of the main cylinder, the doffing cylinder, and the doffing comb.

Inspection of complicated machinery should be performed according to a list to insure that nothing is overlooked. For example, the excessive jolting of the loom may be due to over thirty improper adjustments.¹⁴ With so many adjustments, the value of a check list is obvious.

¹³Kendall, Bull. of the Taylor Society, Dec., 1927, p. 523.

¹⁴Southern Textile Bulletin, XXXV (December 20, 1928), 6.

Utilizing Productive Capacity

The main difficulties here are lack of work and a maledjustment which causes one process or one machine to wait upon another. Production control is concerned only with the latter of these two difficulties. To insure process co-ordination, the operating standards must be cast into production budgets and schedules.¹⁵ Cotton manufacturing processes have both the characteristics of a disintegrative type of manufacturing and also of an assembly type. First the single raw material, cotton, is made into a number of various sized yarns, each with its own characteristics. At least two kinds of this yarn must be brought together to make the cloth. This requires predetermined scheduling which must be based on predetermined standards.

Physical--Product Standardization

Of the mills studied, none was able to standardize its output completely, but all restricted their production to a limited range of fabrics. The composition of these fabrics is standardized to a certain degree by trade practice. The yarn from which the fabrics are made is also standardized. It is practically impossible to spin yarn of an exact weight, but the duck mills usually limit themselves to No. 3 to No. 12 yarn.¹⁶ Yarn standards should be set with proper tolerance limits, which also require standards at various stages prior to the final process. Absolute accuracy is too costly; therefore anything from 9.9 to 10.3 may be acceptable as No. 10 yarn. To produce this yarn the following standards may be required:

Cotton 15/16 inch	
Finishing picker lap	13.49 - 13.51 oz. per yd.
Carded sliver	59 - 61 gr. per yd.
Sliver, first drawing	59.3 - 60.7
second drawing	59.5 - 60.5
third drawing	59.7 - 60.3
Roving, slubber	.62 - .64 hank
intermediate	1.19 - 1.28
jack	2.6 - 2.62
Spinning	9.9 - 10.3

There should also be standards of allowable waste at each of the stages. The sizing should be standardized as to content, preparation and use. The moisture of air and the temperature at

¹⁵ G. W. Ramaker, "Planning and Production Control, " AMA Series No. 74, p. 9.

¹⁶ It requires three lengths of No. 3 yarn, each 840 yards to equal a pound, and 12 lengths of No. 12 yarn.

each stage of production should be standardized.¹⁷

Human Factors

Time and motion studies are the two outstanding elements in standardizing the human factor.

"Motion study consists of dividing work into the most fundamental elements possible; studying these elements separately and in relation to one another and from these elements, when timed, build methods of least waste."¹⁸

Motion study must take into consideration the individual motions as well as the whole cycle of motions, because individual useless motions are to be eliminated, and slow, awkward, difficult or otherwise undesirable ones are to be replaced. A series of exceptionally efficient motions may not permit a smooth and efficient sequence; therefore the sequence study and the individual motion study must both be considered. Unnecessary movements should be questioned, but they may be necessary to give rhythmical sequence to otherwise disjointed and jerky movements.

Fatigue

Physical fatigue seems possible of alleviation through other than a reduction or cessation of the physical effort itself. Present knowledge does not permit the valuation of mental diversion and stimulation as means of counteracting fatigue. The most fruitful studies have been experiments under actual conditions rather than the study of cellular breakdown under work and its repair during periods of relaxation, diversion, or stimulation. Evidence points to the advantage of frequent short rest periods at regular intervals.¹⁹

The Standard Motions

Motion study leads logically to the acceptance of one way to do the job. Undoubtedly for every individual under a certain set of conditions there is one best way of doing the task, and individuals in their abilities do tend to cluster.²⁰ Motions may therefore be determined which are best for an average worker and for the majority of a group of workers, but they cannot be best

¹⁷ Sidney S. Paine, "Fundamental Measurements in a Cotton Mill," Mechanical Engineering, XLVIII (May, 1926), 432-34.

Norman T. Thomas, "Significant Savings in Textile Mill Operations," Bulletin of the Taylor Society, IX (August, 1924), 172.

¹⁸ Frank B. Gilbreth, Applied Motion Study (New York, 1911), p. 43.

¹⁹ Industrial Fatigue Research Board Report No. 42 (1927), quoted in International Management Institute, II, No. 1, p. 9.

²⁰ A. B. Segur, "Labor Costs at Lowest Figures," Manufacturing Industries, XIII (April, 1927), 271.

for everyone. Standard motions are only the means to efficient production, and any worker who can achieve efficient production has fulfilled the main requisite.²¹ The quest for the one best way has been interpreted by English writers as a way that would be mandatory upon everyone, and they have thus condemned it as unsound and unjust.

The Standard Time

Time study is inextricably tied up with motion study, in that the two are mutually interdependent. Naturally there will be differences in the ability of individuals to follow a series of motions rigorously and repeatedly, to go from one motion to another, to see, to comprehend, to manipulate. Research into various fields indicates a definite law of dispersion and concentration which holds throughout nature in any large group of homogeneous data. The clustering at the average and the tapering off on each side of the average may be applied to the time required to perform a task by a large number of persons. Thus an average time constitutes a standard that can be reached by a relatively large number of workers. Selecting individuals for the particular ability required for a certain task will raise this average and will also weed out the extremes, so that the remaining ones will cluster closely about the average. Training this select group will still further cluster the performance times of the individuals.²²

For establishing the standard, time-study men prefer to use a man who is above the average, though not the best man. Labor unions have usually insisted that only an average man should be used. In actual situations varying compromises between these two positions have been made.²³ Most of the time study is done in the shop itself, timing workers at the job. Standards may be set for actual performance, and rest periods may be spaced so that it will be possible to maintain the standard. Also standards may be determined which include an allowance for rest periods and personal needs. After years of study in the machine industries Merrick

²¹ See H. D. Harrison, Industrial Psychology and the Production of Wealth (New York, 1925), p. 22; Oliver Sheldon, Philosophy of Management (New York, 1924), p. 182; Paul M. Atkins, Factory Management (New York, 1926), p. 175; F. W. Taylor, Shop Management (New York, 1911), p. 69; Principles of Scientific Management (New York, 1911), p. 63.

²² Alford, Laws of Management, p. 165.

C. M. Bigelow, Management Handbook, edited by L. P. Alford, p. 962.

²³ Francis Goodell, "The Technician's Point of View," Bulletin of the Taylor Society, XV (April, 1930), 72.

came to the conclusion that there should be five separate allowances covering fatigue, variation in rhythm, unavoidable delays, personal delays, and machine delays. The allowance to be made for the first two of these may be expressed in a formula which takes into consideration the length of the performance cycle and the percentage of handling time to the total time of the cycle.²⁴

Some time study has also been conducted by allowing what seems a reasonable time for each motion and adding to the total time thus obtained an allowance for rest periods and other unavoidable delays.

Incentives

Since the standard also serves as an incentive it has been contended that the standard accepted should be high yet attainable.²⁵ There are very little scientific data on the stimulation value of standards, and it is therefore impossible to draw a curve representing the stimulative force of achieving various percentages of standard output or time.

Time standards as incentives may have a material influence upon the employe welfare; therefore the personnel policies in respect to overworking or overdriving the workers should not be disregarded.

Application of Time and Motion Study

When the necessary motions have been sufficiently subdivided²⁶ and the time studies on that basis recorded, it will be possible to compute the standard time for new combinations of these motions by referring to the files rather than by making new studies. This possible advantage should be considered when outlining time studies. Standards of method and of time should be set with proper regard to Tead's pertinent caution.

"Standards, in short in the personnel field, do not and cannot long continue in force in disassociation from each individual employee's readiness to recognize them as reasonable and authoritative for him no less than for the organization as a whole."²⁷

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D. V. Merrick, Time Studies (New York, 1919), p. 64; "Allowances in Rate Setting," Management Engineering, II (February, 1922), 131.

²⁵

H. A. Overstreet, Scientific Foundations of Business Administration (Baltimore, 1926), p. 322.

²⁶

Where no future operation will require only a part of that motion or sequence of motions.

²⁷

Ordway Tead, Scientific Management in American Industry, edited by the Taylor Society (New York, 1929), p. 404.

Time study and motion study have been severely criticized on the one hand and warmly praised on the other. Hoxie's criticism is that time and motion study are subject to the individual judgment at so many points that it is subject to all the human whims and errors.²⁸ But there is Gilbreth's statement that "there is probably no art or trade that cannot have its output doubled by the application of the principles of motion study,"²⁹ and Hathaway's statement that "time study is as essential to scientific management as the existence of quantitative analysis is to modern chemistry."³⁰

Of the various steps in time and motion study, those given by Harrison constitute a good recent statement. He emphasizes such matters as the obtaining of the consent and, if possible, the complete co-operation of the workers, the judging of change by a decrease of fatigue in the worker for the same output, studying motions in series before timing each element of the motion, the value of rhythm as a preventive of fatigue through the elimination of discrimination and conscious deliberate effort on the part of the worker, the elimination of motions by the better arrangement of tools whenever possible, and the privilege of the worker to use any method as effective as the standard.³¹

Since human beings must operate the machines, it is necessary to relate the human standards to those of the physical factors which they handle. In a cotton mill the work of the laborers is to operate the machines. The tasks here are not thought of in terms of output, but in terms of the number of machines an employe can handle.

In the tending of the machines, whether they be spinning frames, cards, or looms, there are a variety of tasks which must be performed. Some of these require considerable skill while others require practically no skill, or only a manipulative skill which can be developed in a few days. In the interest of lower production costs and better utilization of energy, many mills have separated those skilled tasks from the unskilled ones and have

²⁸ R. F. Hoxie, Scientific Management and Labor (New York, 1916), pp. 46-60.

²⁹ Gilbreth, Primer of Scientific Management (New York, 1914), p. 8.

³⁰ Hathaway, "Elementary Time Study as a Part of the Taylor System of Scientific Management," Industrial Engineering, Vol. XI, No. 2, p. 85.

³¹ Harrison, op. cit., pp. 108-112.

assigned a skilled worker to the one group and an unskilled one to the other group. This made it possible for the skilled worker to perform his limited range of tasks on more machines than formerly. In addition to using unskilled labor for unskilled tasks, this division reduced the range of tasks of a worker and permitted him to develop greater proficiency. A clear placing of tasks became especially important with this division.

Many of the mills saw only the feature which gave each man more machines to tend, or they gave a worker so many more added machines than were warranted by the tasks of which he was relieved that the practice of assigning more machines to a worker is now often termed the "stretch-out" system. The recent labor difficulties in the southern cotton mill district made much of this stretch-out system, objecting to 64 looms per weaver. At the same time, in a chain of five mills in the Carolinas, where proper management had so arranged the work that one weaver was tending 120 looms, only three employees voted in favor of striking.³²

Just how many machines one laborer can tend to advantage is a difficult question which every cotton mill management must answer. A weaver tending only one loom would be idle most of the time, while the loom would receive prompt attention at all times. Two hundred looms to a weaver would probably eliminate all of the idle time of the weaver, but it would increase the idle time of each loom. Somewhere between the extremes lies the optimum point. Just where it is depends upon the duties of the weaver, the frequency of the demands of the machines, the amount of the man's time that is required at each demand, the time required to go from one machine to another, the total amount of working time that can be expected from a man during a day, the relative cost of the man's time and the machine time. The choice is between machine and man idleness, not one to the exclusion of the other, but a combination of the two which results in the lowest operating costs under reasonably standard conditions.³³

It is important to have the wage scale so adjusted that the optimum number of machines per worker is the same from the standpoint of the mill as from that of the worker. If the lowest cost to the mill does not correspond with the highest earning for the worker, the interests of one will have to be sacrificed for

³² F. L. Lamson, "General Administrative Organization and Control," Bulletin of the Taylor Society, XV (June, 1930), 149.

³³ See Albert Palmer, "Cost of Manufacturing and the Multiple system of Loom Operation," Textile World, LXXV (February 2, 1929), 183.

the benefit of the other, or some arbitrary compromise must be made. It is desirable to avoid if possible either of the two. This requires careful study and investigation.

CHAPTER X

PRODUCTION CONTROL

Operating or performance standards constitute an important factor in the control of operations. They are based on prior standards of condition, standards of material, standards of product, standards of equipment, and standards of personal achievements.¹ They predetermine what is to be done, how it is to be done, where it is to be done, and when it is to be done.² Control in its planning aspect sets the objectives and determines under what conditions and by what methods these objectives shall be sought. In its performance aspect, control determines through inspection, observation, records and reports, just what has transpired under the plans. In its correlating and corrective aspects, control manipulates, corrects and revises either the plans or the application of them in such a way that the two may be reasonably harmonized to the greatest advantage of the entire business unit. Control is thus a continuing cycle of determining, observing, and redetermining.

In production control, the application of the standards is effected through routing and scheduling. Routing is the predetermining of the courses of travel of the raw materials in the process of production from machine to machine, and from process to process through the plant. In a continuous process type of industry such as the cotton textile industry this routing function becomes largely automatic with the placing of the machinery and equipment. This placing does not minimize the importance of giving proper attention to routing; it rather maximizes it, since this routing becomes relatively permanent. Even in a continuous process industry such as cotton manufacturing there remains some routing

¹ See Atkins, Factory Management, p. 162; Kimball, The Principles of Industrial Organization; Thomas W. Mitchell, Scientific Management in American Industry (New York and London, 1929), pp. 242-52.

² See Alford, Laws of Management, p. 134; Kimball, Principles of Industrial Admin., pp. 48, 136, 143; Hathaway, Scientific Management in American Industry, p. 319; Alexander H. Church, The Science and Practice of Management, p. 309; W. N. Mitchell, Unpublished materials on production management.

to be done currently. The cotton may progress through the bale-breaker, the opener, three different series of breaker intermediate and finisher pickers, forty cards, two drawing frames, three series of slubbing, intermediate and jack roving frames, one spooling frame, one warper, one slasher, and two hundred looms. In splitting the output of one machine among several machines, some routing is necessary, but it is relatively simple. In addition there is some yarn requiring twisting, and in the weaving department there are often narrow and wide looms which present a problem in routing.

The purpose of scheduling is to assure that the product will pass through the plant without hitch or delay. There are two important considerations in scheduling: first, that the mill and all its various departments be kept fully employed; and, second, that all delivery promises are met. Any products that are to be combined must reach the combination point at the proper time. The weaving is such a process. Here, for example, No. 3 filling yarn is combined with No. 9 warp yarn to produce an 8-ounce duck. The weaving cannot begin until a supply of both of these yarns is available. All of the warp yarn required for a piece of fabric must be ready on the loom beam before the weaving can begin, while the filling yarn is used in regular quantities through the whole time of weaving. In addition the warp yarns must undergo certain preparatory processes after they leave the spinning frames, while the filling yarn is ready for weaving when it leaves the spinning frames. This illustrates the importance of scheduling and dispatching production so that two commodities produced by different processes, and probably at different rates of progress, shall both be finished yarn at such times that their combination can progress without delay and without piling up. This scheduling of an order should begin with the delivery data and work back to the times at which production should start on each yarn.

It is especially necessary to insure a coordination between the planning and the operatives in the mill. For example, sometimes cotton is dirty and must be run through the cleaning processes twice. This disrupts the schedule and whenever it becomes necessary to re-run any product, the planning department should be informed so they can adjust the schedule accordingly. The operators or the inspector should be given standards by which they can determine when to re-run the product, and how to do it.

Underlying facts and situations change, and standards are never absolutely attainable for long periods of time. The causes of the variations may be in the standards themselves or in the operating conditions, but in either case the knowledge of what is going on is imperative. Inspection has already been discussed in the chapters on purchasing and production processes. Due to the

fact that it is costly and usually impractical to change a yarn that is not up to the proper weight it is imperative that not only the product but also the process shall be inspected regularly.

Beginning with the drawing frames there is a continuous and automatic inspection of the product in most cases. Whenever a sliver breaks the machinery is automatically stopped and no under-weight sliver is produced. Automatic stops prevent losing threads on the warper and the loom. However, there is no automatic inspection at the picker stage, and it is necessary to weigh the picker laps to insure the proper weight, since the machinery is so set that a picker lap is drawn out to such length that a standard weight yarn will result if the picker lap was standard weight to begin with. Therefore if the picker lap is either under- or over-weight, the same length of yarn will still be produced, but it will be under- or over-weight. After the picker lap has been passed, any errors in its weight will be reflected in the finished yarn and in the cloth itself.

Inspection may be divided into equipment inspection, including machines and tools, their adjustments, speeds, feeds, etc.; raw material inspection, including length, strength, fineness and cleanliness of the cotton, and content and consistency of the sizing; operating condition inspection, including cleanliness, ventilation, temperature and humidity in the mill; personnel inspection, including general efficiency of the workers, compliance with standards and instruction; and product inspection, including the quality and other standards at various stages during the manufacturing processes and at the end of the final process.

The mill manager, superintendent, and overseers, and cloth inspectors did all the inspecting in the mills observed. In no case was it done according to a rigid predetermined schedule, or on definite predetermined standards.

Records and reports are necessary in addition to inspection. They constitute a history of what has taken place.

"Standards without records are as ineffective as firing at a target would be if the marksman had no means of determining whether he was making hits or not, and vice versa, records without standards would be equivalent to carefully recording the result of every shot but giving the marksman no definite target at which to aim."³

Production records should be mainly in terms of output at the various stages, waste, improper functioning of operations, rates of efficiency, etc.

³ See G. Charter Harrison, *Cost Accounting to Aid Production* (New York: The Engineering Magazine Co., 1921), p. 39.

When standardization has been carried far enough the question of incentives will appear at the very center of production and its control; for if the workers perform according to standard, the machines in standard condition, operated in a standard way, will perform according to standard, and the product of a standard quality will accumulate at a standard rate.

CHAPTER XI

CONTROL

Accounting

As a business grows in size and complexity, it becomes more difficult to show a picture of the operations in financial terms concentrated so the management may comprehend the whole picture, and yet detailed enough to give them the facts so vital to the proper discharge of the executive duties. The function of an adequate system of accounting is to record the history in financial terms as it is being made, in such a way that a clear picture of today's operations are available today, that the efficiencies and their contributing factors can be learned, and that tomorrow's operations may be projected and planned.¹

The expenses should be grouped into small units before as a part of these units they are finally placed in the whole composite picture of the business unit. These groupings may be on the basis of similarity in the items, such as various incomes and expenses; they may be on the basis of physical manipulative processes to which they apply, such as the spinning and weaving; they may be in terms of machines and time; they may be in terms of the individual orders purchased by a customer; they may be in terms of the finished product: they may be in terms of the operating activity grouping; they may be in terms of the control units. A complete cost system may include several of these units; and since incentives, rewards, and control must be in terms of the people having control, there should be an accounting classification of costs and incomes in terms of the control organization.² Manufacturing costs may be gathered by various methods.

¹L. Herbert Ballou, Bulletin of the Taylor Society, XV (February, 1930), p. 27.

²See J. H. Williams, Scientific Management in American Industry, p. 271; Bulletin of the Taylor Society, VIII (April, 1923), 53; Howard Coonley, Scientific Management in American Industry, p. 148; Monard V. Hayes, Accounting for Executive Control (New York: Harpers, 1929), p. 148.

Process Costing³

The simplest application of the process system was found in common use. From the total expenses of a period, the estimated amount which represented the goods in process was deducted and the balance was spread evenly over the pounds of finished fabric produced. This average cost of production was then accepted as the correct cost of manufacturing the average weight cloth. For making bids, the management made an allowance for weight differences. The mill manager in practically every case was quite convinced that he knew just how much difference there was between the cost of the average weight cloth and that of any other weight. This average cost, which almost every mill used, was accepted as sufficient by the mill management in spite of the keen competition under which the difference between acceptable profits and serious losses was only a fraction of a cent per yard of fabric. All the mills computed the manufacturing costs separately, and in making a bid they added to these the cost of the cotton. There was a strong conviction among the mill managers that the replacement cost, rather than the actual cost of the cotton, should be used for purposes of making bids. By this method they hoped to retain for the mill the benefit of advantageous cotton buying.

Job Order Costing

The job order system has been used extensively in various industries, but it has not found much favor in the cotton textile industry. Cotton mill production is in a continuous stream which does not permit identifying separately every order as it goes through the mill from the raw cotton to the finished product.

In addition to this handicap the labor in a cotton mill is expended in operating the machines, and therefore it cannot be allocated directly to the product accurately without first attaching it to the machines and charging an order on the machine hours which it required. This would entail many records and a continuous compilation of machine output during the time the machine was working on a certain order.

Standard Costs

Standard costs may be used in conjunction with both the job order and the process cost methods. The present trend of standard cost accounting is to remedy the defect of the previous methods of so-called post-mortem accounting. They aim to provide a means for expressing the projected course in cost terms and to make it possible to observe progress constantly to permit effect-

³See E. G. Field, "Cost Accounting for Cotton Mills," Textile World, LIX (May 22, 1926), 3481.

ive continuous directive control. They have therefore been termed predetermined and budgeted costs.⁴

Standard costs are relatively new, and their treatment in the literature is still vague and confusing. The variations found in their establishment and use are quite numerous and often radically different from each other. A large part of this lack of definiteness and exactness is due to the incompletely formulated philosophy of cost accounting, which does not set forth a body of complete and generally accepted objectives. For example, one executive expects from his cost system nothing but an accurate reflection of what he has done; the other wants this reflection in terms of what he had expected, stressing the variations; another wants results as a whole, seeking only an average for the whole year; still another wants data upon which he can decide whether each order will be profitable or not.

Standard costs may be designed to give data in such a way that the responsibilities of executives may be checked, and their shortcomings may be shown in such a way that remedial actions can be applied quickly. In addition they often reduce materially the cost of cost records.⁵

Standard costs should predetermine costs which it is expected can and will be achieved and maintained under the expected conditions.⁶ In their complete application they are those costs which will obtain if a standard amount of material costing a standard sum is combined with a standard amount of labor which also costs a standard sum, and if standard expenses are incurred while a standard product is being produced at a standard rate.⁷

Standard costs are applied to the unit of output usually in terms of the three factors, labor, materials, and overhead expenses. In cotton manufacturing the machine is the factor which works on the cotton, and the labor is incurred for no other reason than to keep the machines serviced and operating. It is therefore advisable to attach costs to units of output through the medium of the machines or groups of machines.⁸ Thus all the

⁴See Alford, Laws of Management, p. 20; Hayes, Accounting for Executive Control, p. 21; H. L. Gantt, Organizing for Work (New York: Harcourt, Brace & Co., 1919):

⁵G. Charter Harrison, "What Standard Costs and Budgets Are Doing," Yearbook, National Association of Cost Accountants, 1928, pp. 334-35.

⁶Harrison, Standard Costs (New York: Ronald Press, 1930), p. 228.

⁷E. G. Field, op. cit., p. 3481

⁸W.C. Bennett, "Developing Labor Costs in the Textile Industry," N.A. Cost Accountants, XI (Sept. 15, 1929), 87.

costs must be assembled and reduced to a machine hour basis. The product up to the roving is undifferentiable; therefore it is not necessary to do more than prorate evenly the costs up to this point, since a hank clock on the drawing frames can readily measure the output at this stage. From this point the product is differentiated and standard costs should be established for each type of product, depending upon the machine times it requires at each of the processes.

Standard costs place the emphasis upon variations and not on fluctuating totals, and thus they attempt to answer the question of why the expected was not realized.

Average Variations from Standard.

One of the mills had a cost system by which it determined the average variations from standards which it had established on the basis of its past performance. At the end of each month the total manufacturing costs were obtained from the ledger; these, adjusted for the change in the manufacturing cost of the inventory in process, were taken as the actual manufacturing costs. Then the standard costs for the various fabrics were applied to the quantity of those fabrics produced during the month. The sum of these standard costs times the standard output was then compared with the total actual manufacturing cost. If the total actual cost was 4 per cent more than the sum of the standard costs, then 4 per cent was added to each standard cost figure and it was assumed that each fabric cost 4 per cent more than its own standard. This assumption was usually incorrect, but the manager felt that the error was negligible.

The foregoing procedure may be followed for each group of costs: raw materials, labor, and expenses. The mill mentioned above did keep its raw material separate from the labor and expenses, but it grouped the latter two in its standard. This refinement, however, still gives only an average variation for the labor costs and also for the expenses, but it does isolate the variations between these two.

Actual Variations from Standard

The actual costs may be computed at the end of the period on the same basis used for computing the standard costs. Then the actual variations for each yarn and each fabric can be computed. These can be subdivided to the degree that the causes for each variation in each fabric can be determined. These variations may be analyzed into such causes as the quantity of the material used, the price of the material, the wages of labor, the output rate, the idle time, and the manufacturing expenses in the factory, but these are only the manifestations of causes which lie behind them. However, a knowledge of these manifestations is

quite valuable and is usually much more than management uses.

Actual variations, not on the basis of the units of output but on the basis of materials, labor, and overhead can also be accumulated currently in special accounts. The raw materials may be charged into the inventory account at actual cost and out of it at a standard cost. If the inventory is now taken out at standard cost the account will show the variations from the standard cost for the raw materials. This furnishes a check on the purchasing department. Another method is to charge the raw materials into the inventory account and out of it at actual cost and taking only standard cost into production, carrying the variation to a special raw materials variation account.

All costs may be taken into production at standard with the variations accumulating in special accounts. Thus there may be a separate account for each of the classes of variations, such as raw materials cost, raw materials quantity, labor cost, labor quantity, and manufacturing expenses. This method has the advantage of accumulating variations currently but it adds extra work to the ordinary double entry accounting system.

Computed Variations from Standard

This method has been in a large measure the outgrowth of the efforts of such men as Charter Harrison.¹⁰ The variations from standard are here computed by formulas applied to the actual results.¹¹ First there are certain formulas which are applied to the standards in order to bring the standards in conformity with the actual situations. These include corrections for the different number of working days in the period and for changed wage scales.¹² After the standards have been corrected, other formulas are used to resolve the variations from the corrected standards into their causes in terms of executive responsibility.¹³

Differential Costs

Because of the peculiar conditions existing in a cotton mill the problem of mill balance is an ever-recurring one, and differential costs are exceptionally important.

⁹ See Henry C. Haskell, "Textile Cost Control," Management Engineering, IV (January, 1923), pp. 57-59; C. H. Scovell, NACA Yearbook, 1923, p. 157.

¹⁰ G. Charter Harrison, Standard Costs (New York: The Ronald Press, 1930).

¹¹ Ibid., pp. 52-54, 57.

¹² Ibid., pp. 52-54.

¹³ E. F. Rauss, Manufacturing Industries, XIII (February, 1927), 93.

"How much less he (the cotton mill manager) can quote for such filling-up orders to balance up the losses on unoccupied equipment is his most important problem. A record that assists him to decide this problem, while the buyer is at the other end of the long distance wire, therefore, is the essential part and one of the most profitable of modern cost system."¹⁴
"The value of unit cost calculations upon the two bases of total and shop costs, for comparison against unit sales prices, cannot be overstressed as an administrative tool."¹⁵

Most of the mill managers have learned the importance of keeping their productive capacity employed, but they do not know just how low a price they can afford to quote on an order that will balance their mill nor how high a price they should ask on an order that will unbalance their mill. During temporary periods of poor balance they often keep all of the equipment operating and accumulate stock at certain points, but they usually are not equipped to store the produce in an unfinished condition, and the costs of such production are higher than under ordinary conditions.

The cost of idleness is often as important as the cost of operating. Because the price of cotton is the predominant cost in manufacturing coarse goods, the operating costs have not received adequate attention, and the accounting records have not been designed to show them in such a way that the influence of fixed costs can be readily seen.

Costs for Cotton Mills

After studying the accounting needs of these small coarse-goods cotton mills for a year the writer believes that standard costs should be established and actual costs should be accumulated so that the standard costs may be checked against these. This was not done by any of the mills; so the writer developed such a cost system, which will be described.

Standard costs for every process should be compiled and assembled into standard costs of manufacturing each kind, size, and weight of cloth which the mill produces. In determining these standards of cost it is necessary to determine as accurately as possible a standard production budget and also the expense budget necessary to achieve the production budget.

Cotton manufacturing is almost entirely a machine process, and the costs of producing any fabric are proportionate to the amount of machine time it requires at each process. Costs should

¹⁴ Eugene Szepesi, "Cost Problems of the Textile Industry," NACA Yearbook, 1922, p. 330.

¹⁵ Cconley, Scientific Management in American Industry, p. 155.

therefore be assembled on a machine or a process basis, in the form of machine hour or process hour costs. Production in pounds must then also be put on a machine or process hour basis. The machine hour cost divided by the machine hour output equals the cost per pound of output for that particular machine or process.

The machine hour output can be determined from the machine capacities and from past performance. The machine hour costs must be compiled from the budgeted costs for standard conditions. A detailed technique is necessary to distribute all the various costs to the proper machines and processes in such a way that all manufacturing costs are prorated properly to the operating machines.

If interest on investment is included in these figures the results will show more accurately the relative advantages of manufacturing fabrics that require the use of a large investment and those that do not.¹⁶ The writer favors including it but did not do so in this work because of the opposition of the mill managers. If it is included the investment both in fixed capital and working capital should be determined for every machine or process; for example, the card room should be charged with a proper cost on its investment in fixed assets and in working capital.

The standard expenses according to the expense budget should be distributed to the land, the buildings, the service departments, the production departments, and the administrative department. The buildings usually include a cotton warehouse, an opening building, the main mill, a finished goods warehouse, a boiler room, a machine shop, a supply and repair parts house, a pump house, a mill village, and an office. There may be other buildings or several of these may be included in one building. The service departments include the water system, boiler, power, machine shop, humidifier, and the janitor unit. The production departments are a preliminary cotton unit, carding, slubbing, roving, speeding, spinning, spooling, twisting, warping, tying-in, slashing, narrow plain looms, narrow automatic looms, wide plain looms, wide automatic looms, cloth room and cloth storage and shipping. The administrative department includes the office department.

Depreciation should be computed on each department as a unit. The rates which the Internal Revenue Department approved for one mill are 3 per cent on buildings, 8 per cent on motors and wiring, 6 per cent on the water system, and 4 per cent on the textile machinery.

16

There has been much discussion on this subject. The Cotton Textile Institute urges the mills to include in their costs an amount for interest on the investment.

Taxes should be prorated over all the taxable property on the basis of its appraised value. Special assessments for sewers and streets should be distributed separately and should be allocated either to the mill or to the village, according to their applicability.

The cost of repair parts and supplies should be distributed on the basis of past experience, which should cover the previous three to five years. If there is a separate storehouse for coal and sizing, for example, the costs of maintaining these should be added directly to the coal and sizing costs. Where the percentage of size applied to yarns is varied, it is incorrect to charge a uniform cost for sizing to all yarns; therefore the sizing costs should not be included with supplies but should be added to the yarns separately.

The cost of lighting, consisting of the cost of globes and electricity, should be prorated on the basis of the voltage, since most of the lights in the mill are used continuously during operations.

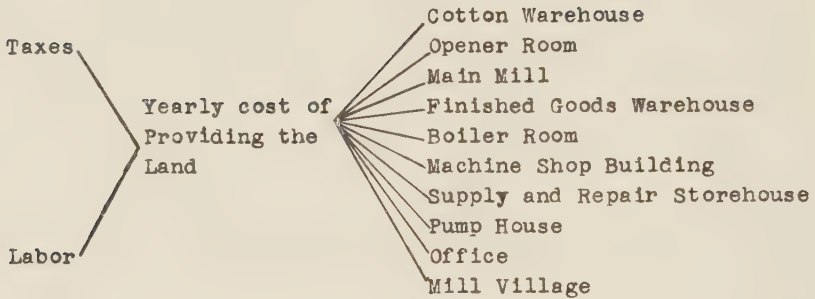
The indirect labor should be added to the units to which it applies. The wages of the janitor should go to the janitorial division; the shop attendant's wages should be charged to the machine shop, and to the pump house if he operates it also; the wages of the yardmen should be divided according to the division of their time, which is usually between keeping the grounds in order and moving raw cotton and baled cloth. Since the mill superintendent usually supervises all the operations of the mill, his salary should be distributed on the basis of the estimated time which each of the various departments demands.

The standard costs of owning the land should be distributed over the units using the land. These costs consist of taxes and the labor for keeping the premises in order.¹⁷ They should be distributed to the various buildings and to the preliminary cotton costs if the cotton is stored on an open lot. The cost of owning the mill site should be distributed over the mill units, while the cost of owning the village site should be distributed over the mill houses (see illustrative Chart I).

The pump house costs consisting of depreciation, taxes, supplies, repairs, lights, labor, superintendence, fire protection and a prorated amount for the land it occupies are added to the water system costs, to be combined with the other water system

¹⁷ Interest on investment, if it is to be included, will consist of the added cost of owning the land.

Chart I



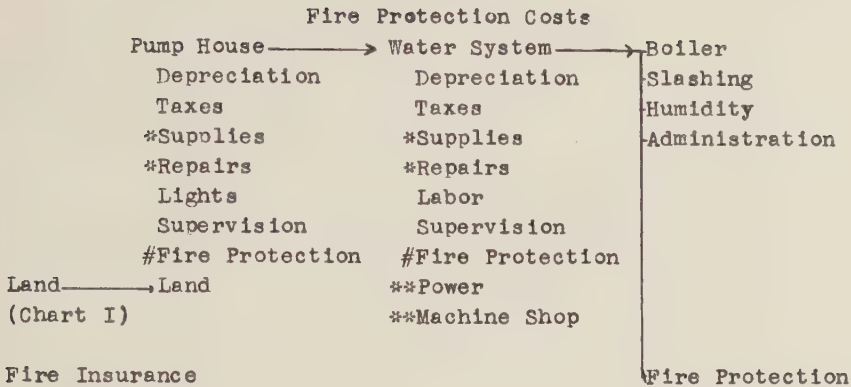
costs of depreciation, taxes, supplies, repairs, labor, supervision, and power.¹⁸ The total water system costs are then distributed over the units for whose benefit the investment in the water system was incurred. The mills use water for slashing purposes, for the boiler, for drinking in the mill and in the mill village, and for fire-fighting purposes. The costs of maintaining and operating the water system capacity beyond that needed for ordinary use should be prorated as fire protection over the investment which it protects. This investment is made up of the buildings, the service departments, the production departments, and the administrative department. The remaining costs should be allocated to the boiler, the slashing department and the humidifying department. If extreme accuracy is desired there should be an allocation to the administrative department for the water used in the office. To the fire protection cost should be added the actual cost of fire insurance.

Special insurance covering raw cotton is chargeable to the preliminary cotton department, and insurance on cotton cloth is chargeable to the cloth storage and shipping department. Burglary insurance should be charged to the administrative department, boiler insurance should be charged to the boiler, public liability insurance should be charged to the administrative department, and workmen's compensation insurance should be prorated over the payroll.

¹⁸ Some of the power costs are properly allocable to the water system, and some of the water system costs should be allocated to the power for fire protection. The proper amount to be allocated to each can be determined algebraically:

$$\begin{aligned}
 &\text{Power costs are } \$5000 \text{ plus } .02 \text{ of Water Costs} \\
 &\text{Water} \qquad \qquad \qquad 1200 \text{ plus } .1 \qquad \qquad \text{Power} \\
 &P = 5000 - .02 (1200 - .1 P) \\
 &.998 P = 5024
 \end{aligned}$$

Chart II



*To include the costs of storing these, which will be developed later, the algebraic equation illustrated on page 151 is necessary.

#These contribute to the costs of fire protection and they also demand fire protection. The proper allocation can be determined by the algebraic computation.

**To be developed later. The algebraic formula is to be used here also.

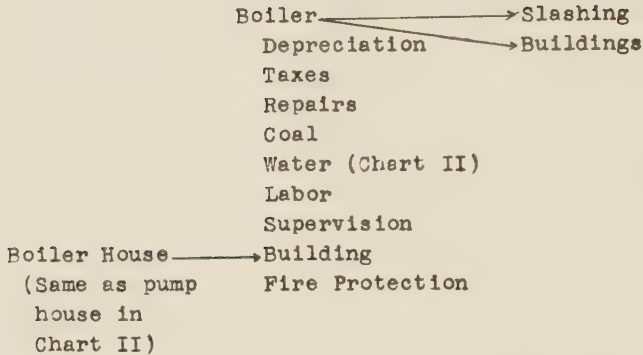
The supply and repair house costs, consisting of depreciation, taxes, fire protection, land costs, labor and supervision, should be distributed on the basis of the past cost of storing the supplies and repairs for each of the departments using them. For simplicity this cost may be added to the cost of the supplies and repairs for distribution. However, it costs much less to store a certain value of cops than it costs to store the same value of starch; so the supply and repair house costs should be distributed independently of the supplies and repairs.

The boiler house costs, consisting of depreciation, taxes, repairs, lights, fire protection, and the cost of the land site should be added to the boiler costs. The remaining boiler costs consist of depreciation, taxes, special boiler explosion insurance, fire protection, coal, water, repairs, lights, attendance, and supervision. The total boiler costs should be distributed to the buildings for heating on the basis of their cubical contents, and to the slashing department on the basis of the steam used.¹⁹

¹⁹ The mills used electric power.

Chart III

Boiler Costs



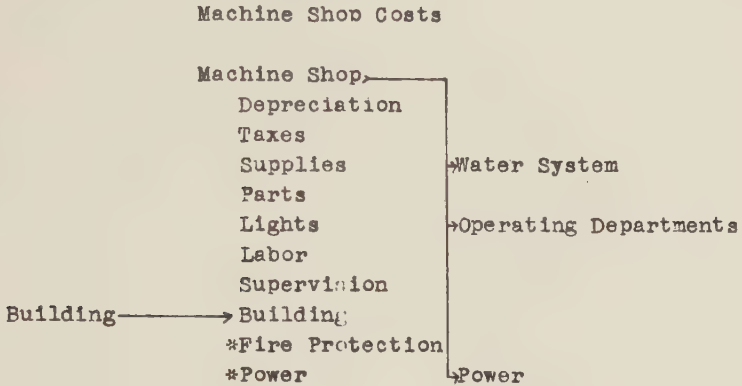
The building costs, consisting of depreciation, taxes, repairs, fire protection and heating plus the cost of providing the site should be prorated to the service and production departments which they house. The cost of the cotton warehouse should be carried to the preliminary cotton costs; costs of the opening building should be added to the carding department; costs of machine shop building should be added to the machine shop costs. The costs of providing and maintaining the mill building should be allocated to the production departments on the basis of floor space.

The janitorial expenses consisting of the wage of the janitor, the depreciation, taxes, repairs, and fire protection on the equipment, the supplies and power are allocated to the production departments on the basis of the services required by each department. Certain departments within the same building require cleaning more often than others, therefore this cost cannot be distributed accurately on the basis of floor space.

The machine shop costs, consisting of depreciation, taxes, lights, repair, supplies, labor, fire protection, building and power costs, should be distributed to the departments using the services of the machine shop. Since some repair work done by the machine shop requires the use of expensive apparatus and some does not, a distribution of the machine shop costs on the basis of the service rendered in time units is incorrect. The correct distribution is obtained by determining the standard cost for each type of equipment used by the machine shop, and charging each repair job with the cost on the basis of this standard. If the machine shop

does work for the water system a portion of its costs should be charged against the water system.

Chart IV



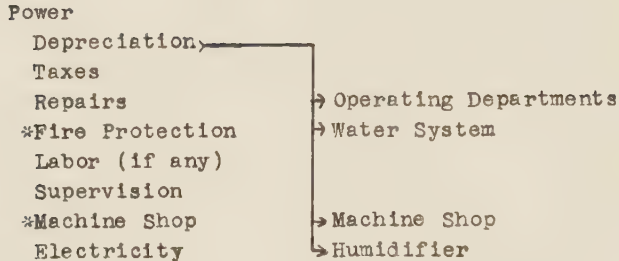
*Equation

The power costs, consisting of depreciation, taxes, repairs, fire protection, machine shop services, and supervision, should be prorated to the departments on the basis of the connected horse power. These are the costs of providing the power facilities. The costs of using the power facilities, consisting of supplies and electricity costs, should be prorated on the basis of the actual power used. It is desirable to distribute power on these two bases because with the group drive system it is usually impossible to use the same percentage of the rated horse power of each motor. The motor operating the compressor, which provides the air for spraying moisture into the air within the mill, is usually a large motor, but it is operated intermittently; therefore the cost of providing that motor is large relative to its operating cost. In one mill the average kilowatt hour input for the motor operating the compressor was only one-third the rated horse power of the motor.

The humidifying costs, consisting of depreciation, taxes, supplies, repairs, fire protection, water and power, should be prorated on the basis of the cubical contents of the departments humidified. For absolute accuracy an adjustment should be made for the varying amount of humidification provided for the various departments.

Chart V

Power Costs



If the foregoing has been followed, all of the manufacturing costs will have been charged to their proper units, and the non-producing unit costs will have been prorated to the producing departments so that all the costs of the mill will have been set against the operating departments which work on the product. These costs will all be on a basis of standard production. When they are divided by the standard output of each of the producing departments the result will be a standard cost per unit of output for each of the producing departments. It is desirable to convert the standard output at every stage to an equivalent of finished product; otherwise an allowance must be made separately for the waste. If the percentage of waste at any process differs from the standard amount, the cost figures will vary from the standard by a proportionate amount.

In a number of cases it is desirable to use algebraic equations to determine the amount of each of two interdependent departments. Sometimes these interdependencies are so insignificant that very little is gained by this refinement. For example, it may not be worth while to charge the supply house with a certain amount for fire protection furnished by the water system.

The order of distribution which has been followed is important because it insures that no costs will be thrown into a department which has once been distributed, and thus one distribution is sufficient. This order has been: depreciation, taxes, supplies, repairs, lights, indirect labor, supervision, land, pump house, water system, fire protection, supply and repair storage house, boiler room, boiler, buildings, janitor service, machine shop, power, and humidity. These are all converged to the production departments. The general scheme of this distribution is shown

graphically in Chart VI.

Chart VI

Allocating Costs to the Production
Departments

Taxes				Pre-Carding
Depreciation				Carding
Supplies				Spinning
Repairs				Spooling
	→ Land	→ Buildings	→ Service Departments	
Indirect Labor				Warping
Supervision				Slashing
Lights				Tying-in
Special Insurance				Weaving
Fire Insurance				Cloth Room

To illustrate the composition of the standard cost of operating a department the following outline shows the costs of operating the slashing department:

Slashing Department Standard Cost

1. Depreciation
2. Taxes
3. Supplies
4. Repairs
5. Fire Protection
 - a. Fire insurance
 - b. Water system
 - (1) Depreciation
 - (2) Taxes
 - (3) Supplies
 - (4) Repairs
 - (5) Fire protection
 - (6) Labor
 - (7) Supervision
 - (8) Building (illustrated below, 7)
 - (9) Machine Shop (illustrated below, 11)
 - (10) Power (illustrated below, 12)
6. Supervision
7. Building
 - a. Depreciation
 - b. Taxes
 - c. Repairs

- d. Lights
- e. Fire protection
- f. Land
 - (1) Taxes
 - (2) Yard men
- g. Heating
 - (1) Taxes
 - (2) Depreciation
 - (3) Coal
 - (4) Water
 - (5) Repairs
 - (6) Fire protection
 - (7) Lights
 - (8) Labor
 - (9) Supervision
 - (10) Building
- 8. Janitor
 - a. Depreciation
 - b. Taxes
 - c. Supplies
 - d. Repairs
 - e. Fire protection
 - f. Labor
 - g. Supervision
 - h. Power (illustrated below, 12)
- 9. Water (for preparing starch)
- 10. Boiler (steam for preparing and applying the starch)
 - (illustrated above, 7g, Heating)
- 11. Machine shop
 - a. Depreciation
 - b. Taxes
 - c. Supplies
 - d. Repairs
 - e. Lights
 - f. Fire protection
 - g. Building
 - h. Labor
 - i. Supervision
 - j. Power
- 12. Power
 - a. Depreciation
 - b. Taxes
 - c. Repairs
 - d. Fire protection
 - e. Labor (if any)
 - f. Supervision
 - g. Machine shop

These constitute the manufacturing expenses of the slashing department on a standard basis. The standard direct labor costs should also be added and the resulting cost will then be the standard manufacturing cost.

After the standard manufacturing costs have been computed for each department, the standard machine hour output must be determined separately for the different products. Since all processes up through the drawing turn out only one product, a sliver of a certain weight, only one standard cost for processing the material up through the drawing process is necessary. If the draft and twist in the roving and spinning processes represent a uniform progression for all yarns through the different roving processes, then the roving and spinning may be considered as one process, and the uniform costs per spindle hour can be allocated to the various yarns on the basis of the spinning time they require.

From the standard costs for the processes, the standard cost of a given yarn may be computed; and from the standard costs of a yarn, the standard costs of a fabric may be computed. If the workers are on a day wage, it is well to include the standard labor cost in the departmental standard cost, because their allocation to the output is on exactly the same basis as that of the manufacturing expenses which have been illustrated. However, for those departments that pay their workers by the piece, this single rate cannot be used; for if workers are on piece rates, then the standard cost should be composed of two elements, the standard costs allocated through the machine and the standard labor costs.

The standard costs of all the various yarns may then be determined by adding the standard cost for that particular yarn for each of the processes through which it must pass. To illustrate:

	Warp Yarns		Filling Yarns	
	No. 10	7	11	9
Carding ^a	\$.02167	.02167	.02167	.02167
Warp Spinning	.02837	.01925		
Filling ^b			.03219	.02583
Spooling ^b	.00602	.00542		
Warping	.00265	.00216		
Slashing ^c	.00715	.00715		
Tying-in	.00274	.00274		
Total Mfg. Costs.	.06860	.05935	.05386	.04750

^aThe costs of manufacturing the sliver up through the drawing process are the same regardless of the kind of yarn that is finally made from the sliver; so they are grouped.

^bThe processes from here on do not apply to the thread that is to go crosswise of the yarn, the filling.

^cThe time for the two remaining processes varies only with the length of the yarn, and not with the weight of the yarn; therefore the costs are the same for No. 10 and No. 7 yarn.

When the total costs of manufacturing all the various kinds of yarn regularly produced by the mill have been computed as shown in the foregoing, the costs for various standard fabrics may be computed in the following manner:

Manufacturing costs of a pound of 7 oz. 29" duck			
Filling Yarn No. 11	\$.05386	use 30% of this yarn for a pound of cloth equals	.01616
Warp Yarn No. 10	.0686	60%	.04416
Sizing material	.0525	10%	.00525
Cost to Mfg. yarns		100%	.06557
Plus the weaving costs			.04
Plus the cloth room costs			.005
Cost of manufacturing a pound of fabric			.11057
Cost (including labor) of manufacturing a pound of 7 oz. 29" duck cloth			.11057
Cost of enough cotton to produce a pound of this fabric			.19243
Cloth room costs			.00182
Total cost per pound of 7 oz., 29" Duck cloth			.30482

In this manner the standard cost for all standard fabrics should be computed. When any unusual fabrics are to be manufactured, the cost can be computed in the same way, if they are to be made from standard yarns. However, if this new fabric is to be woven at a different speed an adjustment must be made.

Compliance with such standard costs depends upon the maintenance of the predetermined expenses, the predetermined rates of output, and the predetermined standard working hours. The analysis of variations from standards is made most readily from these three standard elements. It is an open question whether the cost accounting system should provide the information for calculating how much idle capacity and the falling-off in rate of output actually cost the firm, or whether it is sufficient to show by the production that the rate of output was, for example, only 82 per cent of standard, and that idle time amounted to 10 per cent of the total standard time. It seems that the conversion of these variations into actual dollars serves to give them their relative importance, and it should therefore be done.

Though there is a general recognition of the need for better and more accurate costs, it is difficult to interest the mill managers in anything that is detailed enough to be of real value to them.

The Cotton Textile Institute, a national organization of

cotton manufacturers, is evidencing considerable interest in research to determine better methods of operation and distribution. In conjunction with this work they are urging the mills to adopt better methods of cost-finding. Since the writer has made this study, the Institute has sponsored a study of the cost problems of the cotton duck spinners of the country, and is now recommending to the mills a system which parallels closely that designed by the writer and outlined above.

CHAPTER XII

CONCLUSION

From this limited study only tentative conclusions can be drawn regarding the applicability of scientific thinking to the problems of management in the cotton textile industry.

Practically all of the mills included in this study are small locally-controlled units located in small towns in the cotton-growing districts. Their nearness to the supply of raw cotton and the cheap labor available have been two important factors which have enabled these mills to make reasonable progress without a rigorous weeding-out of inefficiencies in operation and a constant effort to improve their management. As small units they have not been confronted with the management and control problems that require scientific study in larger organizations. Their smallness also accounts for their failure to undertake the research necessary to determine the facts required for the proper solution of some of the problems which confront them.

In general, industry in the southern states has not studied its problems as intensively as they have been studied in the central and eastern sections of the country. Management has not been removed from ownership to so large an extent as it has in the more industrialized sections.

In a number of cases the theories of management were given practical expression in these mills. However, the possibilities of applying scientific thinking to the problems of business management are practically unknown to the managers of most of these mills. They have copied indiscriminately the practices of the New England and the southeastern mills.

The mill management practices indicate at least a partial recognition of the need for business policies, but they do not indicate a proper appreciation of the formulation and use of policies. They have policies on such matters as the purchase of raw cotton, the employment and discharge of workers, the handling of waste, the advisability of overtime and night shifts, and the selling method that is to be used. The policy governing the relation with the selling agent is clearly formulated and expressed in a formal contract. The remaining policies are usually not clearly formulated; they are not written, and no attempt is usually made to measure them. For example, the policy of buying only a sixty-

day supply of cotton expresses merely an arbitrary limit to the speculation in raw cotton. The only written expression of it, if any, is the caution of the board of directors that the mill manager is to refrain as much as possible from speculating in raw cotton.

This lack of definite policies results in vacillating and inconsistent action, and cannot be taken as an indication that proper management does not require definite policies. Although most mills proposed a policy of refraining from speculating in raw cotton, they often purchased an extremely large supply of cotton one year while the next year they purchased scarcely a month's supply ahead. In spite of a policy not to manufacture anything beyond a certain range of goods, it was common for the mill manager to make a fabric beyond that range, which he pushed vigorously for a few months before he decided that it was unprofitable. Though the mill had a policy to buy only cotton of a certain grade, it was observed that if the seller were willing to make a certain price concession the mill often bought cotton much below this stated grade. Many of the professed policies were probably violated as often as they were observed.

On organization matters the practice provided very little data for testing organization theory. The mills are small units and are therefore not confronted with the difficult organizational problems of larger units. The simple organization used by most of these mills was akin to what is usually termed a "line organization." Departments were made by merely dividing the sequence of operations at convenient points. The workers reported directly to the overseer in all matters; the overseer reported directly to the mill superintendent in all matters; and the mill superintendent reported to the general manager. The line of authority and control was direct and all-inclusive. The writer observed, however, that the manager and also the mill superintendent often established additional channels temporarily by taking matters up directly with the workers, rather than going through the intermediate regular channels. Several of the managers guilty of this practice admitted that it should be resorted to sparingly if at all.

In general the need for having authority equal to responsibility was recognized, but it was often violated temporarily, as mentioned above. The mill superintendent was usually given complete control of the mill, and the overseers were given complete control of their respective departments.

There was no recognition of a need for a functional organization, nor for staff advice. Each overseer was responsible for everything within his department, regardless of the variety

of skills which this supervision demanded. The personnel problems, for example, were handled by the overseers as auxiliary to the main task of supervising the mechanical operations. Control, therefore, was ordinarily not divided except when an executive violated the established channels.

In practice no manager was overburdened with an excessive number of persons reporting to him directly. This was due to the smallness of the mills. Ordinarily the carding, spinning, and weaving overseers reported directly to the mill superintendent, and the mill superintendent, the bookkeeper, the stenographer, and cotton buyer reported directly to the general manager. In addition to supervising these subordinates the manager performed the financing and the selling functions; therefore, he was ordinarily occupied with detail and was seldom detached enough to view the whole organization in proper perspective.

The value of definite standards is inadequately recognized. In many cases there were no definite standards, and where there were standards, there was often no inspection to insure their observance. Reasonably adequate standards were used to insure proper weight of the picker lap and to dispose of waste. Mechanical contrivances stopped the machines when a thread broke at the warping or in the loom. Otherwise the standards were inadequate.

Cotton standards are especially inadequate. Government grades, on which cotton is bought, do not measure the spinning value of the cotton; the mills blend cotton from several bales haphazardly with the general hope that a more uniform cotton is thus obtained, and do not blend to secure certain definite qualities for processing. The standards for determining whether certain cotton is to be re-run through the cleaning processes are equally vague. The standards of weight of the product as it comes from the cards, the drawing frames, the roving, and the spinning processes are not definitely set nor checked, with the result that the yarn is often not uniform in weight, and a supposedly No. 9 yarn is often nearer a No. 10 yarn. In addition, when a thread breaks during the slashing process the machinery is not stopped, and the cloth will be deficient in width. The operating standards are not checked to determine whether machines are running at the standard speeds and whether they are producing the standard output. This latter is usually checked only through the records of output, which, however, are not obtained for individual machines at all stages, since hank clocks measuring the output are usually attached only to the drawing frames, the roving frames, and the spinning frames.

The standards for grading cloth are not definitely set, and the inspector must make individual decisions. Also the inspector makes individual decisions as to whether to repair or to

grade down defective cuts of cloth. In no case were the inspectors furnished with rigid standards.

The management theory of separating the planning from the execution was not observed in the general management nor in the production management. The mill superintendent planned and scheduled the production and also supervised its execution. No written orders were used. Had these been larger mills the lack of written orders would probably have been more of a handicap, and the superintendent could not have planned and also supervised execution. The particular situation in the cotton mills forced them to pay considerable attention to scheduling their production. These schedules serve to show when and how much the mill will be unbalanced, and thus enable the management to compute just what type of orders would be most advantageous to bring the mill into a balanced condition. Through this knowledge it is often possible to dovetail in some fabric to utilize otherwise idle equipment. In addition to the necessity of keeping the mill reasonably balanced, the scheduling is also necessary to insure that the two different kinds of yarn which are to be combined into one finished product will both be ready when they are needed. Most of the mills evidence an appreciation of the importance of maintaining an uninterrupted flow of production in the interest of low fabricating costs.

Records and reports are not given sufficient attention. The nearest approach to complete records is in the production department. Daily departmental production records are usually prepared by the overseers and presented to the mill superintendent. The superintendent in turn prepares weekly or bi-weekly production reports for the manager. These reports, however, are not put to the greatest possible use. It is only occasionally that the superintendents compute the percentage of maximum possible output which the departments are producing.

The cost records and reports were not so detailed nor so well designed as the production records. However, practically every mill manager expressed his dissatisfaction with his cost records. In April, 1929, at the New Orleans meeting of the Flat Duck Group of the Cotton Textile Institute, the Institute offered its services in devising a uniform method of determining costs for the duck mills. This work is now well under way.¹

There is very little appreciation of the value of a complete budget of incomes and expenses. Since the mills are small, much of this information is kept in the mind of the mill manager.

¹Letter of March, 1930, from George Duncan, Cost Engineer of the Cotton Textile Institute.

The machine production of cotton manufacturing forces attention to the matter of proper layout. There was almost a standard layout, and movement of materials between processes has been reduced to a minimum.

Much of the mill machinery, if kept in proper repair, will continue reasonably efficient for over twenty-five years. For this reason these mills have been reluctant to take advantage of the more modern labor-saving machines. True, many of them have replaced their plain looms with automatic looms, but none of them have even considered the single-process cleaning machines, which eliminate the need for several men and produce a much more uniform product. Neither have any of these mills installed the newer type spoolers and the unit movable tying-in machine, which makes it unnecessary to remove the harnesses from the looms when a cloth with a similar number of threads is to be woven.

There is only a vague recognition of the importance of economical lot production. None of these mills had made a study of this subject, and they had no idea of the actual cost of changing from one fabric to another. The only recognition of the problem of economic lots was a reluctance to accept small orders.

The personnel factors in these small mills are especially subject to criticism. There is no conception of the workers other than that of hirelings. In most cases, no effort whatever is made to select the workers for certain qualities which the particular jobs require, and the training of the workers is only slightly less haphazard. Proper incentives are not employed. Piece rates are usually paid in the weaving department, because it is easy to measure the output of the individual worker. There is a general desire to stabilize labor costs and to stimulate production through piece rates wherever they can be readily applied. These piece rates are usually set so that the worker must produce a little more than the average output under day wages to earn a sum equal to the day wages. In the other departments day wages are the rule. The only incentive ordinarily used is the presence of the overseer and the speed of the machines. Sometimes the percentage of theoretical production is computed to determine the approximate efficiency of the operation of the various machines, but usually there is no information upon which the loss of productive capacity can be attributed to the worker tending the machine or to the condition of the machine itself.

Methods of performing the tasks have not been studied; therefore each worker is thrown upon his own resources to learn how to perform the task. There has been a recognition of the possibility of dividing tasks. For example, the weaver performs fewer independent functions than formerly, and he performs those few functions on more machines. This permits employing a less

skilled worker to do the unskilled tasks necessary to the operation of the loom. There has been a general division of tasks into those requiring skill and those requiring relatively little skill.

The long hours and low wages are especially contrary to Scientific Management theory. These mills usually operate on a fifty-five hour week. The wages, which are a third less than those in the New England Textile Industry, range from an average of \$0.416 for the skilled loom fixers to \$0.22 for the drawing frame tenders. These wages are approximately the same as those in the North Carolina mills.²

Repairing and replacement of parts in these mills is performed as needed rather than anticipated. In the weaving department, for example, they have a force of repairmen who are usually termed "Smash hands." Systematic inspection and the scheduling of repairs and replacements are not appreciated. The painting of the mill and the replacement of machines are usually performed during shutdown periods.

Most of the mill managers have reconciled themselves to the inevitability of the risks of the industry and have no hopes in hedging. They therefore favor outright speculation in cotton, but they do not take the time to study the market situation adequately; therefore they often suffer heavy speculative losses.

Especially in the last two decades there has accumulated a voluminous literature on the subject of Scientific Management. Professed theories and principles of management may be found in large numbers, and much that is altogether worthless has masqueraded under the colors of Scientific Management. In the foregoing chapters on Policies, Organization, Purchasing, Personnel, Production Requisites, Standardization, Production Control and General Control, the writer has presented and noted through references his conclusions regarding the essence of Scientific Management.³ Here will be summarized only the conclusions regarding the use of Scientific Management in the mills studied and an evaluation of it through this use.

Scientific Management theory has proved its worth in those cases where the cotton mills have put it to the test. The need for scientific thinking applied to business problems, and the need for carefully considered and more consistent action through the use of business policies are undoubtedly recognized, though by no means adequately. The smallness of the mills tends to explain

²C. J. R. Grossman, "The Possibilities of Cotton Manufacturing in Texas," (Austin, Texas, 1928), pp. 42-43.

³The chapters on Policies, Organization, and Personnel are in the complete dissertation, to be found only in the University of Chicago Libraries.

this inadequate recognition, but the major part of the blame can be laid to management.

In the field of organization the practice definitely supports the necessity of limiting the number of subordinates reporting to a superior and of having the authority of any individual equal to his responsibilities. The maintenance of prescribed channels of authority and control is considered valid in theory but it is sometimes violated through the fault of management. Specialized functional supervision, staff advice, and the separation of planning from performance are theories of management which were not found in practice. Due to the smallness of the mills these theories are somewhat less necessary, but in the opinion of the writer the fault lies with the failure of management to use the theories rather than with the theories themselves.

In purchasing, the mills recognized the need for definite standards of quality, and for adjusting the purchases to the market to secure an adequate supply of raw material at an advantageous cost. The practice, however, was much below the theory which the mill managers recognized and attempted to achieve.

In the personnel activities there is a definite recognition of the advantages of placing workmen so that they may do the highest type of work of which they are capable. There is also a recognition of the advantages of training workmen, setting a definite task for them and rewarding them for special accomplishments. None of these theories, however, are applied throughout the mill. This is mainly attributable to management.

The practice is at direct variance with good management theory in the general consideration of labor as a co-partner in a venture, in the low wages, in the failure to select workers for particular skills which will be required of them and in the long hours. The experience of other progressive industries and also that of some of the more advanced textile mills indicates that the failure to comply with the management theories mentioned in the foregoing is a fault of the management.

The production activities which follow the management theory are the maintenance of standard layout of equipment and the maintenance of standard output by product inspection. Pre-planning and scheduling of production were also practiced. Again, these theories were not applied to the limit due to management neglect rather than defects in the theories.

Practice did not follow good management theory in the use of labor-saving equipment, in inspection to maintain machine efficiency, in maintaining proper humidity, and in anticipating and scheduling repairs and replacements to prevent operating interruptions. Here also the reason is the neglect of management rather than faulty theory.

No instruction cards were used, but since the workers merely tend the machines no day-to-day instructions to them are necessary.

The practice evidenced the necessity of proper records and reports, but budgets and adequate cost records were not found. The mills admitted the need for these.

A thorough application of Scientific Management will undoubtedly help the mills to improve their product, lower their costs of manufacturing, market their product more economically, and through these widen the demand for cotton goods.

